COMMITTEE REPORT

# 1996
# ENERGY TECHNOLOGY STATUS REPORT

## REPORT SUMMARY

DECEMBER 1997

**CALIFORNIA ENERGY COMMISSION**

Pete Wilson, *Governor*

P500-96-006


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**ADDITIONAL ACKNOWLEDGEMENTS are extended to members of the previous Research, Development and Demonstration Committee, who guided preparation of a substantial portion of this report.**

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## ABSTRACT

The California Energy Commission's (Commission's) ***Energy Technology Status Report (ETSR)*** is a staff report that responds to legislative requirements specified in Public Resources Code Section 25604. This statute calls for the Commission to publish and submit biennially to the Governor and Legislature a report on energy development trends in the state, including the status of new and existing technologies. In response to this mandate, the ***ETSR*** provides critical input to the Commission's ***Energy Development Report*** which fulfills these legislative requirements and establishes state energy policy recommendations. In addition, the ***ETSR*** supports new power plant siting case evaluations involving demonstration project exemptions and serves as an important reference for use both internally at the Commission and by other research and government organizations.

The ***ETSR*** provides technology evaluations for more than 200 electrical generation, storage, transmission and distribution, and end-use technologies. This report is not an encyclopedia of energy technologies. It contains analysis and description of those technologies which currently comprise California's energy resource base, and new technologies which may potentially meet electrical and thermal needs of California in the next twenty years. The conclusions regarding the status of these technologies are based on California-specific conditions.

This is the fourth edition of the ***ETSR*** and features the following improvements from the previous edition:

- Extensive update on gas combustion technologies to capture recent technological advances.
- A substantially expanded section on transmission and distribution technologies.
- A thoroughly revised section on metering, communications and control technologies.
- A comprehensive update of biomass technologies.
- Changes in some economic assumptions to reflect the altered financing practices due to restructuring of the electric utility industry.
- An expanded chapter on distributed generation technologies to capture deployment issues faced by conventional technologies when deployed in distributed generation mode.

This report provides four levels of detail for technology-specific information. The first level of detail is the ***Report Summary*** which contains a set of matrices depicting the commercial status, research and development goals, and deployment issues for all ***ETSR*** technologies and tables and charts presenting the levelized cost results of key energy technologies. ***Appendices A and B*** provide the greatest amount of detail for each ***ETSR*** technology and contains the unabridged evaluations that are the basis for all ***ETSR*** general technology conclusions and ***Report Summary***

matrices. ***Appendix C, Detailed Economic Analyses***, presents the economic assumptions and discusses the levelized cost computer spreadsheet model used for the levelized cost analyses. Finally, ***Appendix D, Relative Cost of Energy Technologies***, presents Commission staff estimates of the levelized cost of energy produced or saved by the electric generation and end-use technologies that were evaluated using the levelized cost economic model.

The ***ETSR*** represents an effort to compile the best available published information and data on energy technologies rather than to initiate new detailed evaluations. As a result, the level of detail presented varies for each technology evaluation based on the amount of information available.

# 1. INTRODUCTION

## *1.1 Purpose of the Energy Technology Status Report*

California is the world leader in the development of policies that balance the goals of supporting economic development, improving environmental quality, and diversifying the energy supply within the state. Policies for achieving such goals are often based on a comprehensive and timely evaluation of technology options and assessment of their commercial status and potential. For example, the California Energy Commission's (Commission's) ***Energy Development Report (EDR)*** addresses this issue directly by establishing policy recommendations for California energy technology development based on evaluation criteria such as cost, rate impacts, diversity, environmental impacts, operating flexibility, planning flexibility and reliability. The ***Energy Technology Status Report (ETSR)*** is intended to serve as an important resource for this planning effort by supporting the ***EDR*** with a continually updated assessment of more than 200 energy technology options for electric generation, energy storage, transmission and distribution (T&D), and end-use efficiency. This includes identifying the status of commercial availability, areas where research, development, and demonstration (RD&D) are needed most for further development, and issues constraining deployment.

The ***ETSR*** supports the Commission's review of notices of intent and applications for certification of new power plants. Any new thermal power plant 50 megawatts or greater must comply with Commission requirements relative to alternatives, need for electricity generation, environmental impacts and ability to meet technical objectives [Public Resources Code (PRC) Section 25500]. Applicants can, however, receive an exemption from an affirmative finding with respect to need when a proposed facility is determined to be using a noncommercially available technology requiring RD&D [PRC Section 25540.6 (a)(5)]. The ***ETSR*** provides technical input to both the siting case review process and the determination of eligibility for this exemption. Thus, the results of ***ETSR*** energy technology assessments can have a major impact on new generation technology development in California.

Additionally, the ***ETSR*** provides a basis for planning and selecting projects for Commission research and technology commercialization programs by identifying RD&D goals for each technology.

The ***ETSR*** also serves as technology reference for program planning at the Commission, other research and government organizations, consulting firms, energy businesses, and consumers as a source document for technology assessment and comparison. Specifically, the ***ETSR***

- ♦ Provides timely information for policy development and program planning efforts to reflect the impact of RD&D of various technologies.

- ♦ Provides timely information to policy makers and program managers to identify emerging deployment issues and technologies for targeted RD&D.

- Identifies technologies that would continue under monopoly ownership and could benefit from shared RD&D activities.

- Improves customers' bargaining position by providing a range of technology options and information about their approximate cost structure.

- Helps local jurisdictions become familiar with distributed generation technologies as more local jurisdictions are required to grant permits and assess taxes for these new technologies.

- Provides information to small businesses that cannot afford to have in-house resources to generate reliable information on the economics, deployment, and RD&D needs to effectively participate in the emerging energy markets.

- Identifies energy technology options which may have limited use in California but could have major export potential and help economic development in California.

Finally, the ***ETSR*** can fill information needs that arise under electric utility restructuring. The ***ETSR*** analyses have largely been performed for a regulated utility environment. There is growing need to assess how technologies critical for energy diversity, system reliability, environmental benefits, and economic development would fare under a restructured electric industry. The report provides the common base for technology analyses and characterizations essential for development of policies and programs which support technologies that foster competition, facilitate wider consumer choice, and encourage better management of the existing generation and T&D assets.

The ***ETSR*** is intended to be a dynamic document which analyzes the commercial status, RD&D goals, and deployment issues for each technology in the context of the trends in the energy, both thermal energy and electrical services industries. Analyses in response to the prevailing trends are more critical today than in the past due to the rapid and radical changes from electrical industry restructuring. This report has evaluated energy technologies and their deployment issues to capture the impact of the following trends:

- Virtual deregulation of electricity generation assets and their proposed divestment by utilities.

- Increased capital budgets for T&D assets and a need to use T&D assets efficiently.

- Continued "monopoly" ownership and regulation of transmission and possibly distribution systems.

- Limited or nonexistent markets (buyers) who are willing to commit to long-term, guaranteed electricity purchase contracts.

- Generation assets developed and managed by independent entities who, unlike utilities, do not have an obligation to serve sanctioned by a social compact allowing guaranteed recovery of investment.

- Potential unbundling of electrical services where each component could be independently priced and contracted depending on the technology options.

- Unbundling of electrical services and ability to contract for T&D services are forcing price comparisons based on delivered prices and characteristics of the delivered electricity. The economics of electric generation technology alone will have a lesser impact on the pricing and electrical services acquisition of electric generation capacity. As methodologies for assessing monetary impact of system level benefits (dynamic benefits) develop, the busbar costs of generation technologies will become less important in resource acquisition decisions.

- An imminent possibility that electricity will be sold not as a commodity but more like a service with different gradations and prices.

- Transition from cost-based pricing to customer value-based pricing.

- Reduced investment in long-term, shared RD&D and increased focus on short-term RD&D which provide a competitive advantage to those undertaking the effort.

### *1.2 Report Additions and Changes*

The above trends have a profound impact on the availability of current and future technologies. The technology options to meet energy needs of an economic system are never static. Energy technology availability changes in response to the pace of technology development, customer needs, market mechanisms, environmental constraints, fuel availability and the characteristics of institutions responsible for delivering the services. Specifically, this ***ETSR*** incorporates the following additions or changes to its inventory of technologies:

- A thoroughly updated section on gas combustion technologies to reflect the recent technological advances and altered economics due to electrical industry restructuring. This update is critical because some of these technologies form the benchmark standards against which other technologies are compared.

- A comprehensive identification and analysis of T&D technologies.

- An expanded section of distributed generation technologies to reflect the deployment and R&D issues facing some conventional technologies redeployed in distributed generation mode.

- An updated section on metering, communications and control technologies which have the potential to provide system level flexibility and benefits for utilities and to facilitate consumer choice in case of direct access.

- Changes in economic assumptions to reflect the altered financing practices due to restructuring of the electric utility industry.

- Identification of technologies which are no longer allowed because of serious environmental hazards. In addition, those technologies with insignificant or extremely slow technological development were not updated.

- A Glossary of Terms used in the ***ETSR*** that are generally known in the energy field but are not necessarily familiar to the lay person (this is not an exhaustive list but captures some key words and phrases). The Glossary is located at the back of this summary report.

### *1.3 ETSR Organization*

This report provides four levels of detail for technology-specific information. The first level of detail is the ***Report Summary*** which contains a set of matrices depicting the commercial status, research and development goals, and deployment issues for most ***ETSR*** technologies. It is appropriate to use these matrices when an overall assessment is needed or when quick comparisons of several technologies are desired. The ***Report Summary*** also includes the results of detailed levelized cost analyses where necessary and appropriate.

***Appendices A and B*** provide detail for each ***ETSR*** technology. These appendices include unabridged evaluations that are the basis for all ***ETSR*** general technology conclusions and ***Report Summary*** matrices. In addition, economic and technology characterization worksheets are provided for key technologies. ***Appendices A and B*** should be referred to when most detail is needed.

***Appendix C, Detailed Economic Analyses***, presents the economic assumptions and discusses the levelized cost computer spreadsheet model used for the levelized cost analyses. A discussion is also included regarding the "benchmark" cost methodology and the economic worksheet parameters, assumptions and conventions used for assessing both generation and end-use (efficiency) technologies.

Finally, ***Appendix D, Relative Cost of Energy Technologies***, presents Commission staff estimates of the levelized cost of energy produced or saved by the electric generation and end-use technologies that were evaluated using the levelized cost economic model.

### *1.4 Technology Evaluation Components*

To fulfill the ***ETSR's*** purpose, three factors must be evaluated for each technology: commercial status, research and development goals, and deployment issues. Each factor is further discussed.

### *1.4.1 Commercial Status*

Commercial status assessment for all ***ETSR*** technologies indicates energy options now available in California or expected to be available within a 20-year planning period. The base year (first year of operation) for these assessments is 2000 for electric generation technologies, which assumes a five-year lead-time for construction, and 1995 for end-use technologies since they are typically available off-the-shelf. Three criteria are used for commercial status determinations: technology maturity, existence of supplier(s), and competitive cost. All three criteria must be satisfied to at least some degree for a technology to be considered "commercially available" for operation (not for order) in the base year. Technologies where any one criterion is not satisfied are automatically assessed as "not commercially available." The basis for analyzing each technology according to the criteria is further discussed.

**Technology Maturity:** This criterion verifies that each technology has reached a level of technical development demonstrating its readiness for market introduction. Four general phases of technology development have been identified:

- Scientific feasibility
- Technical feasibility
- Engineering feasibility
- Commercial demonstration

Each phase is explained in terms of its major objectives. The purpose of the **scientific feasibility** phase is to demonstrate at an intellectual level the feasibility of a given concept and compliance with known physical laws. The second phase, **technical feasibility,** seeks to confirm the scientific principles underlying a particular concept. This typically involves laboratory-scale experiments that test the general design concept and show necessary materials exist (or might through appropriate research and development) to permit application or operation of the concept. The **engineering feasibility** phase, if successful, verifies that adequate engineering design methods exist to produce a facility or product which may be operated and maintained. This is often accomplished through a reduced-scale demonstration project typically ranging from one-tenth to one-half full system size. The last phase, **commercial demonstration**, is necessary to establish full-scale operation of the technology to verify that it is reliable, durable, safe and has predictable performance characteristics under actual commercial conditions. Considerable overlap could exist between the various development phases. To move ahead, continuous feedback is necessary as designs evolve and are tested and data are acquired. The delineation of development phases permits a technology to be classified as to its "technical maturity."

For a technology to have achieved maturity, it must have evolved through the technology development process and reached the point of a successful commercial demonstration. At a minimum, this typically will involve a full-scale demonstration for electric generation technologies and market introduction of a final product for end-use technologies.

**Existence of Supplier(s):** This criterion is intended to establish whether adequate means exist to make technology available for wide-scale use. For this criterion to be satisfied for generation technologies, either a recognized supplier for required hardware, design expertise and installation skills must exist as demonstrated by the existence of the technology in operation or under construction, or a potential supplier must have indicated an interest in supplying the technology and must have the technical and engineering expertise and the manufacturing infrastructure to supply the technology in commercial quantities.

For most end-use technologies, specialized hardware and design and installation skills are required to satisfy this criterion (*e.g.*, solar systems). Some end-use technologies, however, require only hardware availability because installation procedures are identical to conventional technologies (*e.g.*, energy efficient refrigerators). Passive solar heating and cooling is a unique exception where only special design skills are required to satisfy the criterion because its availability typically relies only on the ability to rearrange standard building materials.

**Competitive Costs:** This criterion establishes whether the levelized cost of using an energy technology is reasonably competitive with other currently available options. This criterion was analyzed by comparing the costs of each energy technology with "benchmark" energy costs for six major ownership sectors involved in decisions to use energy technologies: investor-owned utility, municipal utility, non-utility generator, industrial, commercial and residential. The degree each energy technology is at or below the "benchmark" cost for at least one of the ownership sectors appropriate to that technology is used to assess cost competitiveness.

The competitive cost analysis is based only on monetary costs that include capital, fuel, and operation and maintenance expenses, and excludes all external costs (*i.e.*, environmental, health and safety, etc.) and government subsidies. Social cost analyses, including all of these technology cost components, currently are the subject of extensive studies by many government and research organizations. Social cost analyses are excluded from this version of the ***ETSR***, but might be considered in subsequent versions.

Levelized cost analysis for generation technologies in the previous and current versions of the ***ETSR*** are based on busbar costs. Although this figure of merit is still valid and essential for utilities and energy service suppliers, the changes brought about by industry restructuring may render busbar costs inadequate for proper cost comparison between various options available to customers. A value-based approach adopted by customers may require that the cost of electricity include the delivered cost of electricity. Moreover, the delivered cost will have additional charges reflecting the electrical service components which until now have come packaged in one inseparable bundle. Consequently, generation cost will have to be added to the transmission and distribution (T&D) charges and costs of additional services such as reliability, quality and availability. This approach will result in a shift from cost-based pricing to value-based pricing where each component of service [generation, transmission, distribution and characteristics (such as power quality and reliability)] might make some technologies deployed in distributed generation mode more cost competitive. When compared only on busbar cost, distributed generation technologies are at a disadvantage. Utilities or organizations purchasing bulk power for delivery at distant locations may also figure in the system level impacts (line losses, system stability, frequency control) and consequently use delivered cost as a better measure of cost comparisons. Pending the final outcome of industry restructuring and development of better tools for analyzing the value of each component, this ***ETSR*** still uses the busbar cost as the only figure of merit in developing cost comparisons. In the future, other cost components of electrical services could be included as well.

### *1.4.2 Research, Development and Demonstration Goals*

Energy technologies use mechanical equipment, electric devices, electronic or mechanical controls, and specialized materials that can be improved through research targeted at alternative materials, designs, manufacturing techniques, and volume production. The ultimate objective is to make energy technologies more acceptable to users and society. To achieve this objective, individual RD&D activities frequently focus on a narrow aspect of technology development. Technological advancements usually are the result of an incremental process involving many small improvements that together lead to a commercially viable product or refinement.

Energy policy makers are most concerned with the end results of successful RD&D rather than the details associated with highly specialized incremental developments. This “big picture” point of view allows policy makers to decide on broader issues such as the time frame for commercial availability, necessity and suitability of RD&D funding, and applicability of the technology in California’s energy future.

To facilitate this type of policy analysis, each specific technology evaluation in this report categorizes RD&D goals according to five identified generic research goals. Based on research activities and programs currently underway at government and private sector research facilities, the goals include reduced cost, improved performance, lower operation and maintenance costs, reduced environmental impacts, and reduced building impacts. These generic issues are listed with a full range of subissues in Table 1.

### *1.4.3 Deployment Issues*

A technology can become commercially available through RD&D efforts, yet require many years to achieve widespread market adoption due to constraints that preclude or limit a technology from consideration as a viable alternative. Energy policy makers must evaluate these issues when identifying programs and activities to support preferred energy options. To meet this need, a master list of deployment issues, described below and summarized in Table 2, was developed. Each technology evaluation in this report includes an analysis of deployment issues affecting the technology. These issues are most fully defined for commercially available technologies and less defined for noncommercially available technologies. The absence of an identified deployment issue for a noncommercially available technology does not mean that a certain deployment issue will not exist. Some deployment issues become important only when a technology has penetrated the marketplace above a certain level. All of these issues are discussed below in more detail.

The degree to which a given deployment issue constrains deployment is partially a subjective judgement. In addition, in a state as large and diverse as California, the seriousness of any specific deployment issue may vary from region to region.

## ENVIRONMENTAL CONSTRAINTS

**Air Pollution:** Currently, oxides of sulfur (SOx), oxides of nitrogen (NOx), unburned hydrocarbon (UHC), carbon monoxide (CO), particulates, and lead are regulated by the State of California and the U.S. Environmental Protection Agency. Future regulations (federal and state) concentrate on hazardous air pollutants (National Emission Standard for Hazardous Pollutants [NESHAP]) and airborne toxins. Under local New Source Review (NSR) regulations, electric generating facilities in nonattainment areas must use best available control technology (BACT) and obtain offsets or tradeoffs for pollutants which will be emitted. Carbon dioxide ($CO_2$) also is developing as a global air quality issue.

**Water Pollution:** Water emissions are regulated by the Clean Water Act, usually administered in California by local water districts. The regulations in the Clean Water Act that control emissions probably will be tightened in the future.

**Waste Disposal:** Solids, such as fly-ash from a coal-fired power plant, are generated by many processes and disposal must be located off-site. Disposal of the wastes from each process must be reviewed on a case-by-case basis. In addition, many energy technologies create hazardous wastes in the form of chemicals that exhibit generic characteristics such as corrosivity, reactivity, toxicity or combustibility. Certain organic compounds that are listed in the Resource Conservation Recovery Act, Appendix 8, are classified as hazardous waste. Chemicals determined to be hazardous are difficult and, in some cases, expensive to discard.

**Noise Pollution:** Noise is not federally regulated except within plant boundaries where the Occupational Safety and Health Administration (OSHA) imposes noise limitations. Outside plant boundaries, noise is regulated only by some local governments. In general, noise constraints are easily met except in urban areas. Public pressure, however, can be brought against appropriate agencies to influence plant locations or, in some cases, deny approval of plant construction.

**Radio/Television Signal Interference:** VORTAC stations provide directional and/or range information for air navigation. The Federal Aviation Administration has guidelines for siting of large objects near VORTAC stations. In addition, where new energy facilities impact radio and television signal reception for nearby residents, restrictions may be imposed.

**Thermal Discharge:** The two methods of thermal energy discharge are emitting heat directly into the atmosphere (such as gas turbine exhaust) and emitting heat into a body of water or the atmosphere by means of once-through cooling or a cooling tower. Significant temperature changes that occur in the vicinity of thermal discharge can have a serious impact on the surrounding environment.

**Destruction/Disturbance of Habitat:** Several technologies cause essentially permanent change to land or water use over relatively large areas. Other technologies such as strip mining of coal and harvesting of wood cause at least temporary disturbance of relatively large natural areas. Effects on indigenous wildlife and vegetation must be considered.

## TABLE 1: GENERIC RESEARCH AND DEVELOPMENT GOALS

The following list includes five goals for technology development along with generic research activities that address these goals.

**Reduced Capital Cost**
Capital cost reductions are needed for many energy technologies before they can effectively compete in the marketplace.

- Materials
- Manufacturing
- Installation
- Systems/Design Development
- Resource Development

**Improved Performance**
Unless one or more performance goals are achieved for some technologies, their ultimate economic viability may be limited or fall short of their technological potential. Frequently there is a trade off between capital cost and performance.

- Efficiency
- Availability/Reliability/Durability
- Match Output to Time of Use (Demand)
- Health and Safety
- New Applications

**Lower Operation and Maintenance Costs**
Operation and maintenance costs, including nonrecurring replacement of components and major overhauls, can decrease the economic viability of a technology.

- Systems Integration
- Instrumentation and Controls
- Fuel Modification

**Reduced Environmental Impacts**
Air pollution impacts are a major concern in much of California. Water usage, water discharges, and solid waste disposal are also concerns.

- Pre-Event Cleanup
- Process Modifications
- Post-Event Cleanup
- Adverse Site Impacts

**Reduced Building Impacts**
Market acceptance will be impossible or limited for many end-use technologies unless they can be incorporated into new and existing building stock without significant problems.

- Structural
- Appearance
- Occupant Comfort/Health/Safety

## TABLE 2: GENERIC DEPLOYMENT ISSUES

The following list includes nine issues constraining the deployment of energy technologies along with subissues that address more detailed aspects associated with each issue.

**Environmental Constraints**
- Air Pollution Impacts
- Water Pollution
- Waste Disposal
- Noise Pollution
- Radio/TV Signal Interference
- Thermal Discharge
- Destruction/Disturbance of Habitat
- Scenic Resource Impacts

**Financial Constraints**
- Availability of Financing
- High Capital Costs
- High Operation and Maintenance Costs
- Availability of Tax Incentives

**Fuel and Resource Constraints**
- Availability of Fuel or Resource
- High Cost of Fuel
- Variation in Fuel or Resource Quality

**Governmental Constraints**
- Agency-Government Coordination
- Building Code/Planning Restrictions
- Undependable Avoided Cost Contracts/ Uncertain Cost Structure Due to Restructuring
- Regulatory/Legislative Restrictions
- Permit Restrictions

**Utility Integration Constraints**
- Control of Intermittent Sources
- Need Conformance
- Lack of Demonstrated Reliability/ Performance
- Conformance with Interconnection Requirements
- Lack of Incentive for Utility Companies

**Location Constraints**
- Fuel Delivery Restriction/Cost
- Lack of Suitable Sites
- Adverse Subsidence Impacts
- Availability of Transmission Lines
- Availability of Water
- Risk of Seismic Damage

**Building Constraints**
- Adverse Structural Impacts
- Adverse Appearance Impacts
- Adverse Occupant Impacts
- Minimal Industry Acceptance
- Lack of Incentive for Building Owners/ Developers

**Public Safety Constraints**
- Catastrophic Risks
- Fire Hazards
- Toxic Gas Hazards
- Health Risks

**Socioeconomic Constraints**
- Poor Public Opinion
- Low End-User Awareness
- Complexity of Operation
- Adverse Agricultural Impacts

**Scenic Resource Impacts:** Certain technologies cause substantial changes to pre-existing vistas and natural settings. Local opposition to these changes can lead to regulations restricting development. Siting of windmills or hydroelectric dams are examples of such impacts.

**FINANCIAL CONSTRAINTS**

**Availability of Financing:** Financing of some technologies can be difficult to obtain for reasons such as long payback periods; high initial cost; perceived risk; and uncertainties relative to revenue, cost and the value of the product.

**High Capital Cost:** Some technologies have high or uncertain capital costs that reduce financing options and make them more risky to purchase or develop. Also, the entities developing energy projects without the social compact allowing guaranteed cost recovery face higher finance costs since financiers are reluctant to back projects without long-term power purchase contracts or cost recovery guarantees.

**High Operation and Maintenance Costs:** Some technologies require labor-intensive resources, costly fuel handling procedures, or expensive materials to maintain performance and reliability.

**Uncertainty of Tax Incentives or Unequal Tax Burdens:** The uncertainty of continued availability of a tax credit can limit a developer's ability to obtain financing. In addition, some energy technologies qualify for more tax incentives and other forms of government support (oil, gas and nuclear) than others (conservation, end-use and renewable technologies). Capital intensive technologies face an unequal tax burden compared to those where fuel constitutes a higher cost component.

**FUEL AND RESOURCE CONSTRAINTS**

**Availability of Fuel or Resource:** Conventional fuels used in California are natural gas, petroleum and uranium. Availability of these fuels is related to the worldwide energy picture. Intermittent energy availability affects other technologies such as solar and wind energy. Long-term availability of fuels is a concern for other technologies such as geothermal electric generating plants.

**Variation in Fuel or Resource Quality:** Where the resource or fuel is not of consistent quality, energy projects may be more difficult to plan and finance.

**High Cost of Fuel:** Uncertainty about the long-term relative cost of a particular fuel can limit commitment to its use.

**GOVERNMENTAL CONSTRAINTS**

**Agency-Government Coordination:** Requirements that a technology installation obtain multiple use permits increases installation development time, cost and uncertainty about eventual approval. Occassionally, multi-state cooperation is needed for out-of-state projects involving a sensitive blend of many perspectives.

**Building Code/Planning Restrictions:** Building code and planning restrictions may affect the on-site use of some technologies. Building code and planning requirements also can be used as a barrier to impede construction of new electric generating plants in areas where they are not desired.

**Uncertainty of Cost Due to Restructuring:** Industry restructuring has several issues under CPUC scrutiny with no settlements in sight for the near future. Uncertainty on issues such as a “Competitive Transition Charge” (CTC), pricing of T&D services and ownership of such assets have led to an avoidance of long-term purchases by major buyers, including utilities. Unavailability of long-term power purchase contracts and assured markets have resulted in lack of commitment for major generation projects. Generation capacities are being added with a short-term perspective and in small increments.

**Regulatory/Legislative Restrictions:** Government regulations and legislation can increase the cost of energy production or equipment installations. Health, safety and emissions are just a few of the regulations requiring power plant compliance. Complying with regulations often requires additional equipment and technical expertise that increase project costs.

**Permit Restrictions:** Permitting for new electric generating plants and equipment are highly dependent on the type of technology and site-specific factors. Substantial delays can affect project feasibility.

## UTILITY INTEGRATION CONSTRAINTS

**Control of Intermittent Resources:** Energy technologies such as solar and wind that cannot control their resource availability have a lower capacity and energy values than dispatchable energy technologies. These resources, however, may have acceptable capacity and energy value, along with system support benefits when deployed within the T&D systems.

**Need Conformance:** The Commission makes an integrated assessment of need in its Electricity Report. This assessment requires the Commission’s judgment of how resources will satisfy growth in electricity demand while balancing the factors of environmental quality, conservation, economic health, and public safety and health. Issues may include fuel dependency levels, uncertainty in basic planning assumptions and assurance of flexibility in the electricity system. These strategic issues then determine the Commission’s findings regarding quantity, timing and characteristics of needed resource additions and other generating system modifications. Resources selected for addition should provide at least the same level of benefit at a comparable or lower cost.

**Lack of Demonstrated Reliability/Performance:** Because of prudence review requirements and the utility obligation to serve, utilities require demonstrated performance in any resource addition. Private power developers may face equally stringent performance requirements to ensure that investors are backing proven technologies with guaranteed reliability and performance.

**Conformance with Interconnection Requirements:** Utility requirements for tying into the electricity grid can sometimes impose barriers to new projects. In particular, power quality, safety concerns and equipment specifications must all be satisfied.

**Lack of Incentive for Utility Companies:** During restructuring, electric utility companies have little incentive to upgrade the current technologies unless the investment is small and gains immediate. Projects with long-term economic benefits or potential for quick duplication by competition are less likely to get funded. Such a situation creates a major stumbling block for utility investment in essential technology development that could primarily provide "public goods."

## LOCATION CONSTRAINTS

**Fuel Delivery Restrictions/Cost:** For systems using chemicals or fuels, the site is restricted to locations where delivery is practical. Also, if fuel delivery requires transportation, fuel transportation costs may limit the economic viability of the technology.

**Lack of Suitable Sites:** Many technologies require presence of geographic features, geological resources and climatic conditions that limit their widespread applications.

**Adverse Subsidence Impacts:** Subsidence involves the settling of land areas where underground water resources are depleted. This impact particularly affects some geothermal projects that draw hot water from underground reservoirs without injecting them back into the reservoir. Agricultural industries can be affected by subsidence impacts if slopes of irrigated fields change.

**Availability of Transmission Lines:** Generally, power plants can be developed only where transmission interconnections are reasonably accessible because the cost of extending transmission lines can impose a burden to a project's cost-effectiveness.

**Availability of Water:** Many technologies (in particular, nuclear and oil/gas technologies) typically require large amounts of clean water for cooling. Energy projects using ocean or brackish water to reject heat can have problems with pipe corrosion and scaling.

**Risk of Seismic Damage:** The degree of exposure to seismic activity varies within California. Some technologies may be excluded from a geographic area or become prohibitively expensive due to seismic risk. For example, it is not acceptable to locate nuclear power plants in areas with high seismic activity. Incorporating an ability to withstand seismic disturbances can increase a plant's capital cost.

## BUILDING CONSTRAINTS

**Adverse Structural Impacts:** Some technologies cannot be incorporated in existing buildings without structural modifications. These extra costs can sometimes preclude the use of the technology in retrofit situations. For new construction, most energy technologies' structural requirements can be accommodated with little or no cost premiums.

**Adverse Appearance Impacts:** The use of energy technologies may be substantially reduced where they have a negative effect on building appearance.

**Adverse Occupant Impacts:** The use of energy technologies affecting the comfort of building occupants will be severely limited. In particular, any substantial impacts to space conditioning, lighting, water quality, noise level, or air quality severely limits technology acceptability.

**Minimal Industry Acceptance:** Unless the building industry accepts a new or improved energy technology, it will not be available to most new home buyers because the predominant share of new buildings are built by subdivision developers and "spec" builders. Unless the building industry accepts a technology, market applications will often be limited to replacement of old equipment.

**Lack of Incentive for Building Owners:** For commercial buildings constructed as rental property, owners do not have an incentive to provide cost-effective energy options because tenants rather than building owners usually pay the energy bills. In addition, most tenants do not shop for lower energy costs because energy costs usually do not represent a meaningful portion of total business expenses. Similarly, most residential developers want to minimize up-front building costs.

## PUBLIC SAFETY CONSTRAINTS

**Catastrophic Risks:** Risks arise from the potential for catastrophic failures such as hydroelectric dam failures, ammonia leakage from catalytic reduction systems, and the failure of nuclear power plant containment systems.

**Fire Hazards:** Certain technologies that are candidates for siting in metropolitan areas must be concerned with potential fire hazards.

**Toxic Gas Hazards:** Certain technologies that are candidates for siting in metropolitan areas must be concerned with potential safety hazards involved with gas leakage.

**Health Risks:** Technologies that impose potential health risks both on-site or as the result of fuel or waste-product transport and disposal may face intensive public scrutiny.

## SOCIOECONOMIC CONSTRAINTS

**Poor Public Opinion:** Public opinion can restrict the use of energy technologies. In many cases, poor public opinion has a greater influence over technology use than more substantial economic and environmental constraints. Nuclear, coal and municipal solid waste burning facilities have faced opposition from local communities.

**Low End-User Awareness:** If potential technology users are not aware of specific energy options, those options will not be deployed. It is critical that decision-makers involved in selecting energy technologies are provided with adequate performance and reliability information.

**Complexity of Operation:** For some utility energy technology applications, the complexity of operating procedures may impose a barrier to technology use. For residential and commercial applications, the complexity of energy technologies could be an issue that may require specialized maintenance services or training. Failure to address this issue may make customers reluctant to use them.

**Adverse Agricultural Impacts:** Technologies that release certain metals or reactive chemical compounds or that require the displacement of agricultural land may be limited in their siting in agricultural regions.

# 2. CONCLUSIONS

This chapter provides an overview of all energy technologies assessed in terms of their commercial availability and general conclusions concerning energy technology status, R&D goals and deployment issues. The conclusions are organized according to fuel cycle, electric generation, end-use energy and T&D technologies.

## *2.1 Fuel Cycle Technologies*

### *2.1.1 Fuel Cycle Technologies Commercially Available*

The following fuel cycle technologies have been determined to be commercially available. They are listed as "F" where all three criteria are "fully" satisfied, "MC" where one or more criteria are satisfied under "most conditions," and "LC" where one or more criteria are satisfied under "rare or limited conditions."

**Conventional Fuels:**
Conventional Oil Extraction (F)
Thermally Enhanced Oil Extraction (MC)
Chemical Enhanced Oil Extraction (LC)
Gas Displacement Enhanced Oil Extraction (LC)
Natural Gas (F)
Conventional Coal (F)
Nuclear Fuel Processing (MC)
Liquefied Petroleum Gas (LC)
Liquefied Natural Gas (LC)
Petroleum Coke (MC)

**Alternative Fuels:**
Tar Sands (LC)
Coal Gasification (LC)
Ethanol (LC)
Methanol (from natural gas) (LC)

**Renewable Fuels:**
Hydrothermal Geothermal Resource (LC)
Biomass Fuel (LC)
Municipal Solid Waste (MC)
Solar (LC)
Wind (MC)

### *2.1.2 Fuel Cycle Technologies Not Commercially Available*

The following fuel cycle technologies have been determined to be not commercially available because they do not satisfy to any degree one or more of the commercial availability criteria. Dates of expected commercial availability are indicated in parentheses as either "near-term" (within 12 years), “long-term” (beyond 12 years) or “indeterminate” where there are a number of unresolved RD&D issues or a low likelihood of commercialization in the foreseeable future.

**Alternative Fuels:**
Oil Shale (long-term)
Nuclear Fusion (long-term)
Direct Coal Liquefaction (near-term)
Indirect Coal Liquefaction (near-term)
Coal Pyrolysis (near-term)
Hydrogen (long-term)

**Renewable Fuels:**
Hot Dry Rock Geothermal Resource (near-term)
Magma Geothermal Resource (long-term)

### *2.1.3 Fuel Cycle Technologies General Conclusions*

- The fuel cycles for conventional fossil fuels are well established. Pulverized coal is the predominant fuel for electric generation nationally. Natural gas is the predominant fuel source for electric generation in California. Petroleum-derived fuels are used primarily for transportation, although they were used for electricity generation in California about 20 years ago.

- There is a need to continue progress to develop technologies that improve air emissions because of California’s stringent air emission standards. Regardless of abundance or low cost in the near future, fuels such as natural gas may face constrained use unless technologies that help meet air quality improvements are developed.

- Several technologies for processing coal as a fuel are being pursued at the national level. Electric generation based on advanced and clean coal technologies could be available in the near-term.

- The primary research goals for alternative and renewable fuel options are to reduce cost and improve performance for fuel manufacturing, handling, storage, and transportation.

- Advances in conventional fuel-based modular electric generation technologies, coupled with opportunities provided by deregulation, will bring fuel-to-electricity conversion closer to the end-user. This may possibly affect delivery and distribution practices of conventional fossil fuels. For example, microcogeneration systems would require that the natural gas used in the system be delivered under a required level of pressure. Most local distribution companies may not currently have this ability.

- Resource development and resource collection are the primary barriers to alternative and renewable fuel use. These barriers demand solutions in light of continued low natural gas prices.

- ♦ Environmental and resource issues need to be resolved for renewable energy sources such as geothermal, biomass and municipal solid waste.

## *2.2 Electric Generation Technologies*

### *2.2.1 Electric Generation Technologies Commercially Available*

The following electric generation technologies are determined to be commercially available in California. They are listed as “F” where all three criteria are “fully” satisfied, “MC” where one or more criteria are satisfied under “most conditions,” and “LC” where one or more criteria are satisfied under “rare or limited conditions.”

**Oil and Gas Combustion:**
Conventional Rankine Cycle (LC)
Supercritical Rankine Cycle (LC)
Simple Cycle Gas Turbine (F)
Conventional Combined Cycle (F)
Steam Recuperated Gas Turbines (LC)
Small-Scale Turbines (MC)
Kalina Combined Cycle (LC)

**Coal:**
Conventional Steam Boiler Rankine Cycle (MC)
Atmospheric Fluidized Bed Combustion (MC)

**Nuclear Fission:**
Pressurized Water Reactor (MC)
Boiling Water Reactor (MC)

**Geothermal:**
Vapor-Dominated Resources (MC)
Liquid-Dominated Resource Flashed Steam (LC)
Liquid-Dominated Resource Flashed Steam with pH Modification Process (MC)
Liquid-Dominated Resource Binary Cycle (MC)
Biphase Topping Cycle (LC)
Biphase Bottoming Cycle (LC)

**Hydroelectric:**
Conventional (MC)

**Biomass-Fired Plants:**
Direct Combustion (LC)
Gasification (LC)
Anaerobic Fermentation (LC)

**Municipal Solid Waste:**
Mass Burn (MC)
Refuse-Derived Fuel Spreader Stoker (LC)
Fluidized Bed Boiler (LC)
Landfill Gas Recovery (MC)

**Cogeneration:**
Gas Turbine-Based Systems with Heat Recovery (MC)
Gas Turbine-Based Systems with Combined Cycle (MC)
Reciprocating Engine (MC)
Back-Pressure Topping Steam Turbine (LC)
Extraction Topping Steam Turbine (LC)
Low-Pressure Steam Bottoming Turbine (MC)
Organic Rankine Bottoming Engine (LC)
Packaged Cogeneration (LC)

**Wind:**
Utility-Scale Applications (MC)

**Solar Thermal Electric:**
Parabolic Troughs (LC)

**Ocean Energy Conversion:**
Wave Energy Conversion (LC)

**Storage Systems:**
Conventional Pumped Hydroelectric (MC)
Modular Pumped Hydroelectric (LC)
Compressed Air Energy Storage (LC)
Utility-scale Batteries (LC)
Micro Superconducting Magnetic Energy Storage (LC)

### *2.2.2 Electric Generation Technologies Not Commercially Available*

The following generation technologies have been determined to be not commercially available because they do not satisfy to any degree one or more of the commercial status criteria. Dates of expected commercial availability are indicated in parentheses as either “near-term” (within 12 years); “long-term” (beyond 12 years); or “indeterminate” if significant unresolved R&D goals exist or if commercialization is unlikely in the foreseeable future.

**Oil and Gas:**
Intercooled Steam Recuperated Gas Turbine (near-term)
Chemically Recuperated Gas Turbine (near-term)
Humid Air Turbine (near-term)
Intercooled Reheat Combined Cycle (near-term)
Intercooled Aeroderivative Gas Turbine (near-term)

**Coal:**
Pressurized Fluidized Bed Combustion (near-term)
Integrated Coal Gasification Combined-Cycle (near-term)
Integrated Gasification Humid Air Turbine (near-term)
Direct Coal-Fired Combustion (near-term)
Direct Coal-Fired Diesel (near-term)
Indirectly Coal-Fired Combined Cycle (indeterminate)
Magnetohydrodynamics (indeterminate)

**Nuclear Fission:**
High-Temperature Gas-Cooled Reactor (near-term)
Liquid Metal Fast Breeder Reactor (indeterminate)

**Nuclear Fusion:**
High-Temperature Nuclear Fusion (long-term)
Cold Nuclear Fusion (long-term)

**Geothermal:**
Liquid-Dominated Resource Kalina Cycle (near-term)

**Municipal Solid Waste:**
Refuse-Derived Fuel Co-Firing (20% Coal) (near-term)
Pyrolysis/Thermal Gasification (near-term)

**Cogeneration:**
Stirling Engines (near-term)
Fuel Cell Cogenerators (near-term)

**Solar Thermal Electric:**
Central Receivers (near-term)
Parabolic Dishes (near-term)
Salt Ponds (indeterminate)

**Photovoltaics:**
Utility-Scale Systems (near-term)

**Ocean Energy Conversion:**
Tidal Energy (near-term)
Ocean Thermal Energy Conversion (long-term)

**Fuel Cells:**
Phosphoric Acid Utility-Scale Applications (near-term)
Molten Carbonate (near-term)
Solid Oxide (near-term)

Alkaline (long-term)
Proton Exchange Membrane (near-term)

### *2.2.3 Electric Generation Technologies General Observations and Conclusions*

The following conclusions are based on the impact of trends in the electric industry on commercial availability, RD&D goals, and deployment issues of the technologies discussed in the report. The salient conclusions are as follows:

- ♦ Development of economic, small-scale technologies, aided by mass manufacturing techniques, will enable distributed generation (defined broadly, including storage) to compete with central plant generation. Critical deployment and a few RD&D issues related to plant control and integration with current utility systems, however, need to be resolved.

- ♦ The uncertainty caused by lack of firm power purchase contracts for large capacity, problems and complexities inherent in transmission, and movement toward direct access and customer choice also create opportunities for distributed generation.

- ♦ For electric generation technologies which are not commercially available, the reduced cost and improved performance RD&D goals and the deployment issues (such as financial constraints) are frequently listed as potential “show stoppers.” The RD&D goals, deployment issues, and noncommercial status follow one from the other. High first cost and high operational cost (poor performance, low durability, high operations and maintenance cost) are common reasons why a technology is not commercially available and has financial constraints on use. While a technology is in the RD&D phase, production costs are high because of high engineering and fabrication costs. Once a technology has been successfully demonstrated and operational experienceis obtained, better and lower cost designs, components, and materials can be chosen. These improvements, however, will not necessarily lead to commercialization of the technology.

- ♦ Major improvements in aeroderivative gas generation technologies and their applications to heavy frame machines have increased efficiency to the level such that the division between baseload, peaking, and intermediate duty cycles has become blurred. Electric generation using natural gas has become the de facto standard (benchmark) against which the costs of all other energy technologies are measured.

- ♦ Although natural gas-based generation technologies are substantially commercialized, RD&D funding is needed to design and demonstrate advanced gas turbine cycles. The advanced gas turbine cycles have the potential for low capital cost and high fuel-to-electricity conversion efficiency. Work in this field has slowed, however, as the limited market in the near-term for these advanced technologies do not justify major investments.

- ♦ Compared to other generation technologies, gas combustion technologies have fewer deployment constraints. Conventional combined cycle technology benefits from military aircraft engine developments in efficiency and high temperature materials. Natural gas is widely available in California, and atmospheric emissions are low.

- ♦ Advanced pulverized coal, integrated coal gasification combined cycle, and integrated gasification humid air turbines may offer California environmentally acceptable coal-based options. Fluidized bed coal combustion technologies could be available and cost competitive if natural gas prices escalate.

- ♦ Most clean coal technologies have significant RD&D needs for cost reduction, systems design/development, performance, improved efficiency, and demonstrated lower operation and maintenance costs.

- ♦ As a group, coal technologies face multiple deployment issues associated with environmental, financial, resource, utility integration, and location constraints. Coal generation technologies emit more carbon dioxide than natural gas generation technologies. Deployment could be limited if carbon dioxide emission limits are imposed. Resource constraints become a factor for California because of limited indigenous resources and transportation costs for out-of-state resources to California. Siting and operation of coal-fueled cogeneration power plants, however, show that the many deployment issues can be overcome. At the present time, California utilities have ownership interests in out-of-state pulverized coal power plants but operate no coal-fired plants in-state.

- ♦ Nuclear energy technologies are faced with major RD&D issues relative to cost reduction, standardized design development, improved performance, lower operation and maintenance costs, and reduced environmental impacts. California law prohibits the siting of nuclear power plants until the scientific and engineering feasibility of high level radioactive waste disposal is demonstrated.

- ♦ Nuclear fusion technologies are long-term prospects that depend on meeting cost and performance RD&D goals. Future RD&D funding may come primarily from European and Southeast Asian countries.

- ♦ Crystalline photovoltaic cell and module technology is technically proven but cost competitive only in certain applications. Major cooperative demonstration programs will help to lower capital costs and to resolve deployment issues. Alternative, and potentially lower-cost, cells require material and cell efficiency improvements, manufacturing process development, and demonstrated durability.

- ♦ Phosphoric acid fuel cells are commercially available at the 200 kW scale but have high capital costs. Molten carbonate, solid oxide, and proton exchange membrane fuel cells are expected to be commercially available in the near-term.

- Fuel cell technologies need material and system design development and must achieve the RD&D goals for reduced cost and improved performance. The manufacturing infrastructure needs to be developed to reduce capital cost.

- The site availability for storage technology options is limited due to environmental, governmental, and location constraints. A few pumped hydroelectric sites could be developed to meet the needs of restructured and deregulated electric markets.

- Compressed air energy storage, utility-scale batteries, and micro supermagmetic energy storage technologies are available under limited conditions. The deployment of the latter two, however, is motivated more by power quality and system level benefits than as storage technologies.

- High capital costs and the need for improved performance are major RD&D challenges associated with most renewable energy technologies including geothermal, biomass, municipal solid waste, wind, solar thermal electric, photovoltaics, and ocean energy conversion.

- Renewable and alternative energy technologies often are confronted with financial and utility integration constraints. Expiration of Standard Offer contracts for capacity and energy, coupled with uncertainty due to electric industry restructuring, is severely limiting deployment of high cost technologies except in sporadic value-added applications.

- Resource constraints are potential "show stoppers" limiting the extensive use of certain renewable energy technologies in California, including vapor-dominated and advanced geothermal resources, hydroelectric, biomass, and ocean energy conversion.

- Although not always identified in this report, materials issues tend to impact the cost and performance of technologies such as heat exchangers, photovoltaic cells, and solar collectors. Problems such as high materials costs, fabrication cost, corrosion, erosion, fatigue, and thermal stress constrain the commercial availability of these technologies.

- Deployment issues associated with commercially available technologies are opportunities for government or other organizations or individuals to accelerate the use of a technology, perhaps at a relatively low cost.

- For modular technologies, the high first cost results from high cost in tooling and labor. The development of a manufacturing infrastructure is an important RD&D goal. Once production has started, cost reductions can be expected to follow a "learning curve." With higher volume, production costs are much lower than those of small production runs. Financing the high capital cost of the early units, before the economies-of-scale in manufacturing can be achieved, is a major deployment issue. This factor is critical as electric generation equipment is becoming a manufactured product versus a site-built facility.

### *2.3 End-Use Technologies*

### *2.3.1 End-Use Technologies Commercially Available*

The following end-use generation technologies are determined to be commercially available. They are listed as “F” where all three criteria are “fully” satisfied, “MC” where one or more criteria are satisfied under “most conditions,” and “LC” where one or more criteria are satisfied under “rare or limited conditions.”

**Water Heating:**
Pulse Combustion Water Heater (LC)
Condensing Commercial Water Heater (MC)
Heat Pump Water Heater (F)
Tankless Water Heater (MC)
Passive Solar Water Heater (MC)
Active Solar Water Heater (MC)
Waste Heat Recovery Water Heater (MC)
Hot Water Demand System (F)

**Space Heating:**
Recuperating Furnaces (LC)
Pulse Combustion Furnaces (LC)

**Space Cooling:**
Desiccant Cooling (LC)
Gas Absorption Cooling (MC)
Gas Engine Cooling (LC)
High-Efficiency Air Conditioner (MC)
Evaporative Cooling (F)
Heat Recovery Absorption Cooling (LC)
Roof Spray Cooling (LC)

**Combined Heating and Cooling:**
Gas-Fired Heat Pumps (LC)
High-Efficiency Air Source Heat Pumps (F)
Water Source Heat Pumps (MC)
Geothermal Heat Pumps (MC)
Dual Source Heat Pumps (LC)
Heat Pump Setback Thermostats (LC)
Integrated Appliances (MC)
Heat Pipe Assisted Air Conditioning (LC)
Passive Solar Heating and Cooling (MC)

**Building Envelope Technologies:**
Advanced Glazing Films and Coatings (MC)
Gas Filled Glazings (MC)

Fenestration Control High R-Value Systems (F)
Advanced Insulation (F)
Radiant Barriers (LC)

**Lighting:**
Energy Efficient Incandescent Reflector Lamps (MC)
Energy Efficient Incandescent Tungsten-Halogen Lamps (MC)
Compact Fluorescent Lighting (F)
Full-Size Fluorescent Lighting (F)
Mercury Vapor HID Lamps (LC)
Metal Halide HID Lamps (MC)
High Pressure Sodium HID Lamps (MC)
Low Pressure Sodium HID Lamps (MC)
Daylighting (F)
Lumen Maintenance Lighting Control (LC)
Occupancy Scheduling Lighting Control (F)
Fine Tuning Lighting Control (F)
Load Shedding Lighting Control (F)

**Appliances:**
High-Efficiency Refrigerators (LC)
Advanced Residential Electric Cooktops (LC)
Residential Solar Cookers (MC)
Advanced Commercial Fryers (MC)
Advanced Commercial Griddles (LC)
Advanced Commercial Ovens (LC)
Advanced Dishwashers (F)
Advanced Clothes Washers (F)
Advanced Clothes Dryers (F)
Advanced Office Equipment (F)

**Industrial Applications:**
High-Temperature Insulation (F)
Boiler and Steam System Improvements (F)
Waste Heat Recovery (F)
Pinch Analysis (F)
Advanced Industrial Controls (MC)
Industrial Process Load Adjustment (F)
Industrial Process Heat Pumps (LC)
Freeze Concentration (F)
Membrane Processes (MC)
Laser Processing (LC)
Advanced Industrial Refrigeration (MC)
Infrared Heating (MC)
Microwave Heating (MC)

Solar Industrial Process Heating (LC)
Radiant Low NOx Tube Burners (LC)

**Advanced Motors:**
Programmable DC Motors (LC)
Variable Speed Drive AC Motors (F)

**Load Management:**
Time-of-Use, Dynamic Price Sensing, and Response Metering (MC)
Communication and Control Systems Technologies (MC)
Energy Management Systems (F)
Thermal Energy Storage (MC)

**Community-Scale Technology:**
District Heating and Cooling (MC)
Geothermal Direct Use (MC)
Multistage Flash Distillation (F)
Multiple Effect Distillation (F)
Reverse Osmosis (F)
Mechanical and Thermal Vapor Compression (F)

**Distributed Generation:**
Distributed Reciprocating Engines (MC)
Distributed Small-Scale Turbines (MC)

### *2.3.2 End-Use Technologies Not Commercially Available*

The following end-use technologies have been determined to be not commercially available because they do not satisfy to any degree one or more of the commercial status criteria. Dates of expected commercial availability are indicated in parentheses as either “near-term” (within 12 years), “long-term” (beyond 12 years), or “indeterminate” (if they have excessive unresolved R&D issues or low likelihood of commercialization in the foreseeable future).

**Water Heating:**
Radiant Burner Storage Type Water Heater (near-term)
Thermophotovoltaic Gas Water Heater (near-term)
Passive Hot Water Recovery System (near-term)
Hot Water Heater Vent Damper (near-term)

**Space Heating:**
Heat Pipe Furnaces (near-term)
Active Solar Heating (indeterminate)

**Space Cooling:**
Active Solar Cooling (near-term)

**Building Envelope Technologies:**
Aerogel Glazing High R-Value Insulation (near-term)
Evacuated Glazing High R-Value Insulation (near-term)
Switchable Windows (near-term)

**Lighting:**
E-lamps (near-term)
Light Pipes (near-term)
Fiber Optic Systems (near-term)

**Appliances:**
Advanced Insulation for Refrigerators (near-term)
Advanced Residential Gas Ovens (near-term)
Advanced Commercial Burners (near-term)

**Industrial Applications:**
Advanced Glass Processing (near-term)
Advanced Gas-Fired Heaters (near-term)
Advanced Radiant Heat Transfer (near-term)

**Distributed Generation (grid-connected):**
Distributed Photovoltaic Systems (near-term)
Distributed Fuel Cell Systems (near-term)
Distributed Solar Dish Stirling Systems (near-term)
Distributed Wind Systems (near-term)

### *2.3.3 End-Use Technologies General Conclusions*

- The lack of incentive for building owners and developers to incorporate energy efficiency measures and minimal industry acceptance of cost-effective energy technologies limit the deployment of most end-use technologies provided as original equipment in new buildings. This is because building owners and developers have no incentive to improve energy efficiency where tenants or new owners pay their own energy bills. Until builders include more efficient technologies in new buildings, the only major market for energy efficient end-use technologies will be for replacing old equipment. Without government or utility actions, these constraints will be mitigated only when demands of tenants and building buyers create a market advantage to include cost-effective energy technologies.

- Low end-user awareness is a particularly critical deployment issue for new end-use technologies. Unlike the users of electric generation technologies, end-users are widely dispersed, have fewer resources, and lack familiarity with technical concepts.

- Substantial energy savings can be derived from many commercially available end-use technologies that have limited use though they are highly cost competitive. These technologies include condensing and waste heat recovery commercial water heating, heat pump water heaters, ceramic fiber burner heating, evaporative cooling, passive solar heating and cooling, high efficiency lighting and control systems, high efficiency refrigerators, advanced clothes washers and dryers, advanced office equipment, advanced industrial technologies, variable speed drive AC motors, energy management systems, and customer controlled automated feedback transmission systems. Thus, government or utility programs targeted at the “lack of incentive for building owners and developers” and “low end-user awareness” issues identified in the previous two items could yield reduced energy consumption.

- ♦ Restructuring of the electric industry has diminished utility participation in rebates for end-use technologies used for demand-side management. Such technologies are likely to see limited deployment because of high first cost and long-term payback. This will affect the level of market penetration for established technologies and delay commercialization of new end-use technologies.

- ♦ Most new lighting technologies are cost-effective energy options for new commercial buildings.

- ♦ Most advanced energy conservation technologies have favorable levelized costs compared to electric generation technologies.

- ♦ A broad range in the levelized cost of heating and cooling technologies exists because their economic viability is dependent on load requirements. Typically, high-cost heating and cooling technologies are not cost-competitive in many of California’s climate areas because of short heating and/or cooling seasons or moderate temperatures.

## *2.4 Transmission and Distribution Technologies*

### *2.4.1 Transmission and Distribution Technologies Commercially Available*

The following transmission and distribution technologies are determined to be commercially available. They are listed as "F" where all three criteria are "fully" satisfied, "MC" where one or more criteria are satisfied under "most conditions," and "LC" where one or more criteria are satisfied under "rare or limited conditions."

**Transmission:**

Flexible AC Transmission Systems (FACTS) - Thyristor-Controlled Series Compensation (TCSC) (LC)
Underground Transmission Solid Dielectric Cables (F)
Underground Transmission Guided Boring (F)

**Distribution:**

Automatic Meter Reading (MC)
Magnetic Shielding for EMF Management (MC)
Distribution Static Compensator (DSTATCOM) (LC)
Dynamic Voltage Restorer (LC)

**Transmission and Distribution System Support:**
Automated Mapping/Facilities Management/Geographic Information Systems (AM/FM/GIS) (MC)
Communication and Information Technologies (MC)
Supervisory Control and Data Acquisition (SCADA) (MC)
Helicopter Use for Live Wire Maintenance (F)
National Lightning Detection Network (NDLN)/Fault Analysis and Lightning Location Systems (FALLS) (F)
Severe Storm Detection (LC)
Composite Poles (MC)

**Mature Transmission and Distribution Technologies:**
Solid-State Arresters (F)
High Phase Order Transmission (LC)
Amorphous-Core Transformers (F)

### *2.4.2 Transmission and Distribution Technologies Not Commercially Available:*

The following transmission and distribution technologies have been determined to be not commercially available because they do not satisfy to any degree one or more of the commercial status criteria. Dates of expected commercial availability are indicated in parentheses as either "near-term" (within 12 years), "long-term" (beyond 12 years), or "indeterminate" (if they have excessive unresolved R&D issues or low likelihood of commercialization in the foreseeable future).

**Transmission:**
Flexible AC Transmission Systems (FACTS) - Static Synchronous Compensator (STATCOM) (near-term)
Flexible AC Transmission Systems - Unified Power Flow Controller (UPFC) (near-term)
Flexible AC Transmission Systems - Thyristor-Controlled Phase Angle Regulator (TCPR or TCPAR) (near-term)
Flexible AC Transmission Systems - Thyristor-Controlled Braking Resistor (TCBR) (indeterminate)
Underground Tranmission Superconducting Cables (near-term)
Dynamic Thermal Rating of Conductor Capacity (DTR) (near-term)

**Distribution:**
EMF Design Guidelines for EMF Management (indeterminate)
Solid-State Circuit Breakers (near-term)

**Transmission and Distribution System Support:**
Resource and Planning Software Tools (near-term)
Resource and Planning Operation Tools - Inter-Control Communications Protocol (ICCP) (near-term)
Reliability-Centered Maintenance (near-term)

Robotic Maintenance Strategies (near-term)
Ground-Penetrating Radar (near-term)
Explosion Monitoring and Control (near-term)
Superconducting Current Limiter (near-term)

**Mature Technologies:**
HVDC Circuit Breakers (near-term)

### *2.4.3 Transmission and Distribution Technologies General Conclusions*

♦ The T&D sector of the electric industry is currently facing major challenges. Due to impending deregulation intended in part to lower electricity prices, electric utilities are streamlining T&D operations to achieve better asset utilization. Difficulty in constructing new transmission lines due to environmental constraints and unconfirmed but perceived health risks from electromagnetic fields (EMFs) are forcing utilities to operate the existing T&D system most efficiently.

♦ The electric industry is seeing continued increases in sophisticated computer software and hardware; information transmittal and communications technologies; control and monitoring devices and systems; transistors; and thyristors. These developments have provided the necessary tools to bring about efficiency and improved management of T&D assets.

♦ Increasingly, electricity customers have come to require uninterrupted power not troubled by voltage sags, surges, or other fluctuations and irregularities. All of these factors translate into new concerns about, and solutions for, T&D system flexibility, reliability and power quality control.

♦ T&D operations are moving toward real-time monitoring and quick-acting controls that improve the efficiency and flexibility of the system. Examples include flexible AC transmission systems (FACTS) (based on thyristor technology); “custom power” quality control for distribution level (based on advanced transistors); software for controlling power flow; supervisory control and data acquisition systems (SCADA); and dynamic monitoring and thermal ratings of power lines.

♦ Communications and information systems are rapidly becoming more sophisticated and find numerous applications in T&D. Improvements include the following:
  - ♦ faster computer hardware and software for monitoring and controlling power flow;
  - ♦ more options for transmitting data, such as fiber optics, radio frequencies, telephone lines, the power lines themselves, etc.;
  - ♦ integration of differing communications and computer protocols to improve operations, analysis, and billing systems (e.g., utility communication architecture [UCA]);

  - distribution automation (DA) including automated meter reading, billing and accumulation of customer usage data;
  - SCADA; and
  - automated mapping/facilities management/geographical information systems (AM/FM/GIS) and global positioning systems (GPS) — computerized mapping and geographical data from satellites to enhance inventory and maintenance tracking capabilities and other operations.

- With limited growth in power line construction, utilities are placing more emphasis on maintenance of existing T&D systems. Under development are sophisticated methods to determine the condition of system components; better maintenance schedules based on the actual condition of parts; and cost-cutting maintenance strategies such as live-line work using helicopters.

- Nationally, the electric industry is taking advantage of better design capabilities for substations and power line configurations with these goals in mind:
  - to reduce EMF;
  - to prevent damage to sensitive geographical areas such as using guided boring to lay underground lines with minimal damage and disruption; and
  - to reduce damage from lightning and other storm events.

- Composite materials are replacing traditional materials in T&D system components. Composite insulators are much lighter and more durable than ceramic ones. Composite poles can be used effectively where wood rot and woodpeckers are problems.

- The trends toward better monitoring systems, faster and more accurate power flow control, flexible communications and data retrieval, and other streamlined operations are expected to continue for some time. Additional results of deregulation on T&D operations are yet to be determined.

# 3. TECHNOLOGY EVALUATION SUMMARY

This chapter summarizes the results of technology assessments for a broad range of energy options that are potentially available to California. The results are based on detailed technology evaluations included in Appendices A and B of the ***ETSR***. The matrices are organized into fuel cycle, electric generation, end-use energy, and transmission and distribution (T&D) technology sections. This chapter also includes results of cash-flow analyses that were used to evaluate cost-competitiveness for both electric generation and end-use energy technologies. Appendix C provides a full description of this economic analysis process.

## *3.1 Technology Evaluation Matrix*

The Technology Evaluation Matrix in Figure 1 summarizes the results of assessments of each energy technology for the three evaluation factors: commercial status; research, development and demonstration goals (RD&D); and deployment issues.

The commercial status section of the matrix provides assessments of each technology according to three criteria: technology maturity, existence of supplier(s), and cost competitiveness, along with an overall commercial availability determination. Because a technology must satisfy all the criteria to at least some degree to be judged commercially available, the overall determination was “not commercially available” if any one criterion was not satisfied.

The matrix uses a graphic system to indicate the evaluation results. The darker the box under each criterion, the less a technology satisfies that criterion: a white box indicates a criterion is fully satisfied; a light gray box means that a criterion is satisfied under most conditions; a diagonal striped box indicates that the criterion is satisfied under only limited or rare conditions; and a black box means the criterion is not satisfied under any conditions.

The commercial availability column uses the same graphic code: a white box indicates a technology is fully commercialized; a light gray box means commercial availability under most conditions; a diagonal striped box indicates commercial availability under only limited or rare conditions; and a black box indicates a technology is not commercially available.

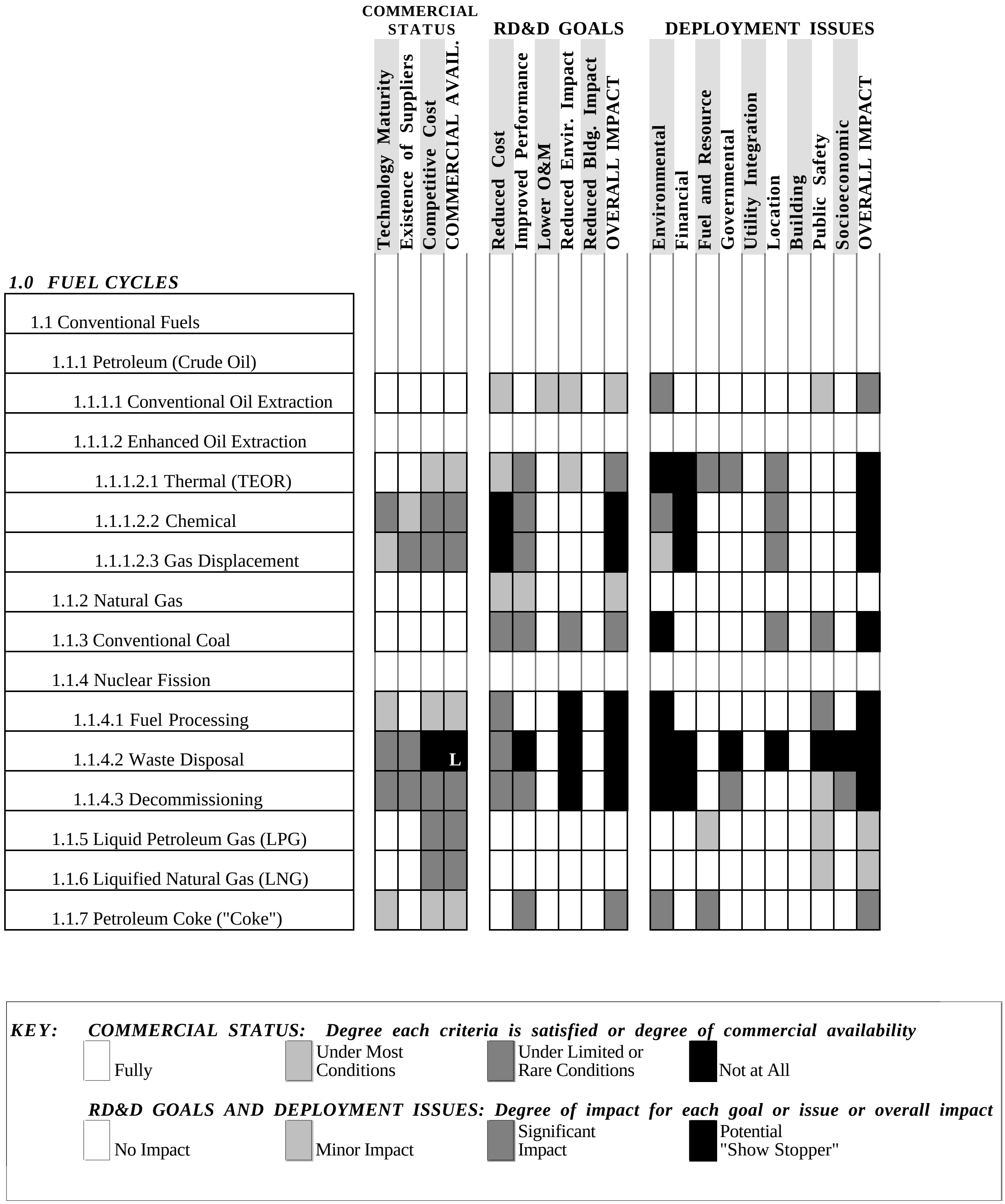
Technologies determined to be “not commercially available” also include staff’s best estimates of expected future availability within California in the “commercial availability” column. These estimates are based on information from experts and literature on specific technology RD&D and commercialization activities. Due to the uncertainty involved in forecasting energy demand and technological breakthroughs, however, these estimates are limited to broad designations as either “N” for near-term (within 12 years); “L” for long-term (beyond 12 years); or “I” for “indeterminate” where noncommercial technologies have too many unresolved RD&D or deployment issues or limited activity for further development. Thus, technologies noted as “near-term” are expected to be commercially available, at least to a limited degree, before the year 2007; technologies noted as “long-term” are not expected to be commercially available to any degree until after the year 2007; and technologies noted as “indeterminate” have too many uncertainties to project commercial availability or are unlikely ever to be commercially available.

The RD&D goals section of the matrix includes results of evaluating each technology according to the five major categories in the generic list of goals from Table 1. The deployment issues section of the matrix includes results of evaluating each technology according to the nine major categories in the generic list of deployment issues from Table 2. Both of these matrix sections provide an assessment of each major category as well as the overall impact.

These sections of the matrix use a graphic system similar to the commercial status matrix. The darker a color, the greater the impact: a white box indicates no impact; a light gray box indicates a minor impact; a diagonal striped box indicates a significant impact; and a black box indicates a potential “show stopper” unless resolved. The overall assessment is based on the highest impact assessed for any generic goal or issue. Thus, technologies with only one high impact generic goal or issue would have a higher overall impact than technologies with many less serious goals or issues.

The deployment issues section of the matrix should be reviewed after the RD&D goals section. If a technology has an RD&D goal identified as a potential “show stopper,” then that goal may be a far more formidable barrier to commercial use of the technology than any of the deployment issues. In the early stages of technology development, the deployment issues may not be well defined. Deployment issues increase in importance and become better defined as RD&D goals are achieved. Therefore, the absence of identified deployment issues for technologies that have potential “show stopper” RD&D goals does not mean that deployment issues will not arise as the technology approaches commercial availability.

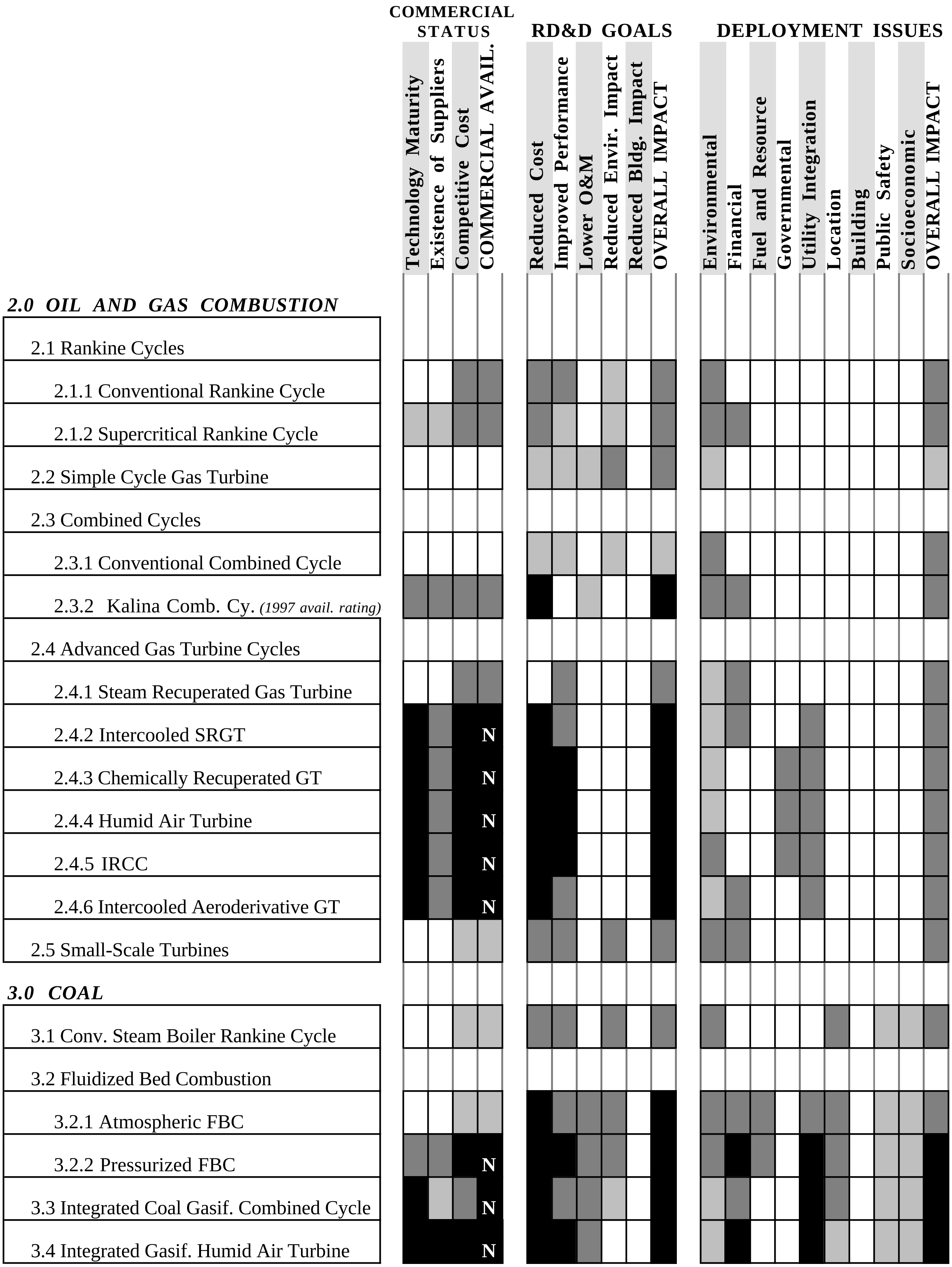
# *FIGURE 1: Technology Evaluation Matrix*



## *FIGURE 1: Technology Evaluation Matrix (continued)*

| | COMMERCIAL STATUS | | | | RD&D GOALS | | | | | | DEPLOYMENT ISSUES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technology Maturity | Existence of Suppliers | Competitive Cost | COMMERCIAL AVAIL. | Reduced Cost | Improved Performance | Lower O&M | Reduced Envir. Impact | Reduced Bldg. Impact | OVERALL IMPACT | Environmental | Financial | Fuel and Resource | Governmental | Utility Integration | Location | Building | Public Safety | | |
| 1.2 Alternative Fuels | | | | | | | | | | | | | | | | | | | | |
| 1.2.1 Oil Shale | | | | L | | | | | | | | | | | | | | | | |
| 1.2.2 Tar Sands | | | | | | | | | | | | | | | | | | | | |
| 1.2.3 Nuclear Fusion | | | | L | | | | | | | | | | | | | | | | |
| 1.2.4 Coal | | | | | | | | | | | | | | | | | | | | |
| 1.2.4.1 Coal Gasification | | | | | | | | | | | | | | | | | | | | |
| 1.2.4.2 Direct Liquefaction | | | | N | | | | | | | | | | | | | | | | |
| 1.2.4.3 Indirect Liquefaction | | | | N | | | | | | | | | | | | | | | | |
| 1.2.4.4 Pyrolysis | | | | N | | | | | | | | | | | | | | | | |
| 1.2.5 Ethanol | | | | | | | | | | | | | | | | | | | | |
| 1.2.6 Methanol (from Natural Gas) | | | | | | | | | | | | | | | | | | | | |
| 1.2.7 Hydrogen | | | | L | | | | | | | | | | | | | | | | |
| 1.3 Renewable Fuels | | | | | | | | | | | | | | | | | | | | |
| 1.3.1 Geothermal | | | | | | | | | | | | | | | | | | | | |
| 1.3.1.1 Hydrothermal | | | | N | | | | | | | | | | | | | | | | |
| 1.3.1.2 Hot Dry Rock | | | | N | | | | | | | | | | | | | | | | |
| 1.3.1.3 Magma | | | | L | | | | | | | | | | | | | | | | |
| 1.3.2 Biomass Fuel | | | | | | | | | | | | | | | | | | | | |
| 1.3.3 Municipal Solid Waste | | | | | | | | | | | | | | | | | | | | |
| 1.3.4 Solar Resource | | | | | | | | | | | | | | | | | | | | |
| 1.3.5 Wind | | | | | | | | | | | | | | | | | | | | |

## *FIGURE 1: Technology Evaluation Matrix (continued)*



## *FIGURE 1: Technology Evaluation Matrix (continued)*

| | COMMERCIAL STATUS | | | | RD&D GOALS | | | | | | DEPLOYMENT ISSUES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technology Maturity | Existence of Suppliers | Competitive Cost | COMMERCIAL AVAIL. | Reduced Cost | Improved Performance | Lower O&M | Reduced Envir. Impact | Reduced Bldg. Impact | OVERALL IMPACT | Environmental | Financial | Fuel and Resource | Governmental | Utility Integration | Location | Building | Public Safety | | |
| 3.5 Brayton Cycles | | | | | | | | | | | | | | | | | | | | |
| 3.5.1 Direct Coal-Fired Combustion | | | | N | | | | | | | | | | | | | | | | |
| 3.5.2 Direct Coal-Fired Diesel | | | | N | | | | | | | | | | | | | | | | |
| 3.6 Indirectly Coal-Fired Combined Cycle | | | | I | | | | | | | | | | | | | | | | |
| 3.7 Magnetohydrodynamics | | | | I | | | | | | | | | | | | | | | | |
| ***4.0 NUCLEAR FISSION*** | | | | | | | | | | | | | | | | | | | | |
| 4.1 Pressurized Water Reactor | | | | | | | | | | | | | | | | | | | | |
| 4.2 Boiling Water Reactor | | | | | | | | | | | | | | | | | | | | |
| 4.3 High Temp. Gas Cooled Reactor | | | | L | | | | | | | | | | | | | | | | |
| 4.4 Liquid Metal Fast Breeder Reactor | | | | L | | | | | | | | | | | | | | | | |
| ***5.0 NUCLEAR FUSION*** | | | | | | | | | | | | | | | | | | | | |
| 5.1 High Temperature | | | | L | | | | | | | | | | | | | | | | |
| 5.2 Cold Fusion | | | | I | | | | | | | | | | | | | | | | |
| ***6.0 GEOTHERMAL*** | | | | | | | | | | | | | | | | | | | | |
| 6.1 Vapor-Dominated Resources | | | | | | | | | | | | | | | | | | | | |
| 6.2 Liquid-Dominated Resources | | | | | | | | | | | | | | | | | | | | |
| 6.2.1 Flashed Steam Plants | | | | | | | | | | | | | | | | | | | | |
| 6.2.1.1 Flashed Steam | | | | | | | | | | | | | | | | | | | | |
| 6.2.1.2 Geo Brine pH Mod. Process | | | | | | | | | | | | | | | | | | | | |

***KEY:*** ***COMMERCIAL STATUS: Degree each criteria is satisfied or degree of commercial availability***

Fully — Under Most Conditions — Under Limited or Rare Conditions — Not at All

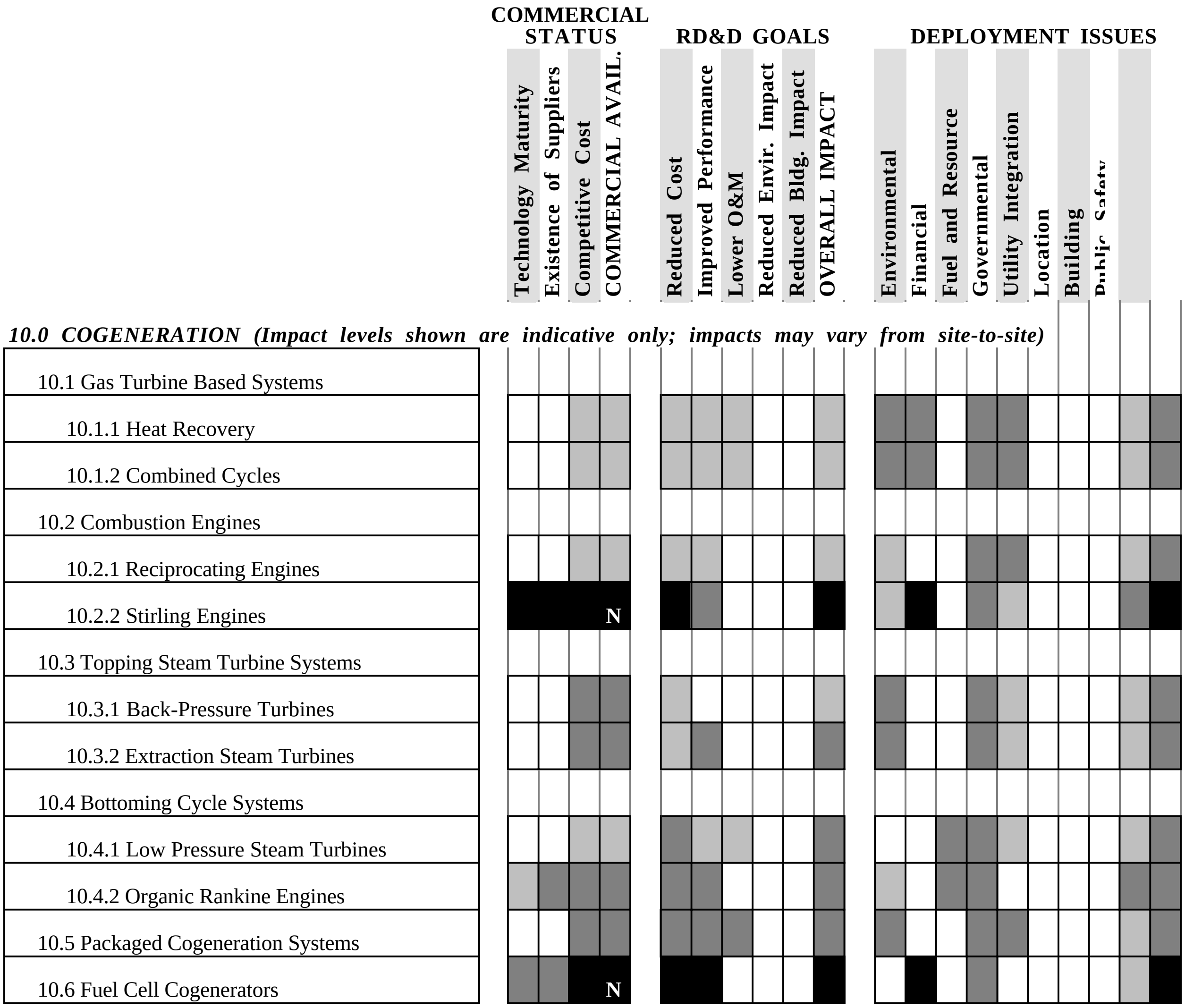
***RD&D GOALS AND DEPLOYMENT ISSUES: Degree of impact for each goal or issue or overall impact***

No Impact — Minor Impact — Significant Impact — Potential "Show Stopper"

## *FIGURE 1: Technology Evaluation Matrix (continued)*

| | COMMERCIAL STATUS | | | | RD&D GOALS | | | | | | DEPLOYMENT ISSUES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technology Maturity | Existence of Suppliers | Competitive Cost | COMMERCIAL AVAIL. | Reduced Cost | Improved Performance | Lower O&M | Reduced Envir. Impact | Reduced Bldg. Impact | OVERALL IMPACT | Environmental | Financial | Fuel and Resource | Governmental | Utility Integration | Location | Building | Public Safety | Socioeconomic | OVERALL IMPACT |
| 6.2.2 Binary Plants | | | | | | | | | | | | | | | | | | | | |
| 6.2.2.1 Binary Cycle | | | | | | | | | | | | | | | | | | | | |
| 6.2.2.2 Kalina Cycle | | | | N | | | | | | | | | | | | | | | | |
| 6.2.3 Biphase Plants | | | | | | | | | | | | | | | | | | | | |
| 6.2.3.1 Biphase Topping Cycle | | | | | | | | | | | | | | | | | | | | |
| 6.2.3.2 Biphase Bottoming Cycle | | | | | | | | | | | | | | | | | | | | |
| ***7.0 HYDROELECTRIC*** | | | | | | | | | | | | | | | | | | | | |
| 7.1 Conventional Hydroelectric | | | | | | | | | | | | | | | | | | | | |
| 7.2 Hydro Uprating | | | | | | | | | | | | | | | | | | | | |
| 7.3 Hydro Retrofit | | | | | | | | | | | | | | | | | | | | |
| ***8.0 BIOMASS FIRED PLANTS*** | | | | | | | | | | | | | | | | | | | | |
| 8.1 Direct Combustion | | | | | | | | | | | | | | | | | | | | |
| 8.2 Gasification | | | | | | | | | | | | | | | | | | | | |
| 8.3 Anaerobic Fermentation | | | | | | | | | | | | | | | | | | | | |
| ***9.0 MUNICIPAL SOLID WASTE*** | | | | | | | | | | | | | | | | | | | | |
| 9.1 Direct Combustion | | | | | | | | | | | | | | | | | | | | |
| 9.1.1 Mass Burn | | | | | | | | | | | | | | | | | | | | |
| 9.1.2 Refuse-Derived Fuel | | | | | | | | | | | | | | | | | | | | |
| 9.1.2.1 RDF Spreader-Stoker | | | | | | | | | | | | | | | | | | | | |
| 9.1.2.2 Co-Firing (20% Coal) | | | | N | | | | | | | | | | | | | | | | |
| 9.1.2.3 Fluidized Bed Boilers | | | | | | | | | | | | | | | | | | | | |
| 9.2 Gasification | | | | | | | | | | | | | | | | | | | | |
| 9.2.1 Pyrolysis/Thermal Gasification | | | | N | | | | | | | | | | | | | | | | |
| 9.2.2 Landfill Gas Recovery | | | | | | | | | | | | | | | | | | | | |

## *FIGURE 1: Technology Evaluation Matrix (continued)*



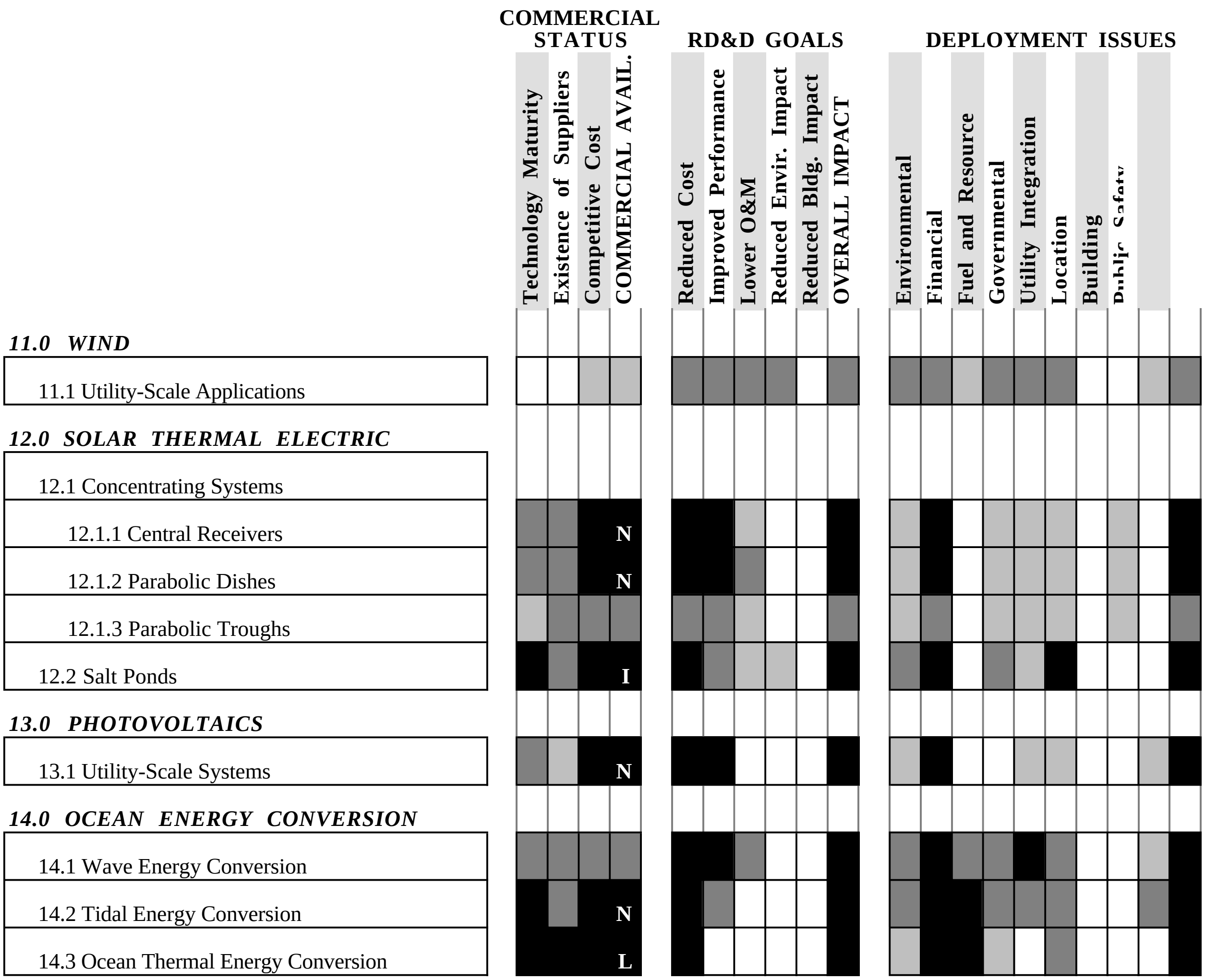

***KEY:*** ***COMMERCIAL STATUS: Degree each criteria is satisfied or degree of commercial availability***

Fully | Under Most Conditions | Under Limited or Rare Conditions | Not at All

***RD&D GOALS AND DEPLOYMENT ISSUES: Degree of impact for each goal or issue or overall impact***

No Impact | Minor Impact | Significant Impact | Potential "Show Stopper"

# *FIGURE 1: Technology Evaluation Matrix (continued)*




***KEY:*** ***COMMERCIAL STATUS:*** ***Degree each criteria is satisfied or degree of commercial availability***

Fully | Under Most Conditions | Under Limited or Rare Conditions | Not at All

***RD&D GOALS AND DEPLOYMENT ISSUES:*** ***Degree of impact for each goal or issue or overall impact***

No Impact | Minor Impact | Significant Impact | Potential "Show Stopper"

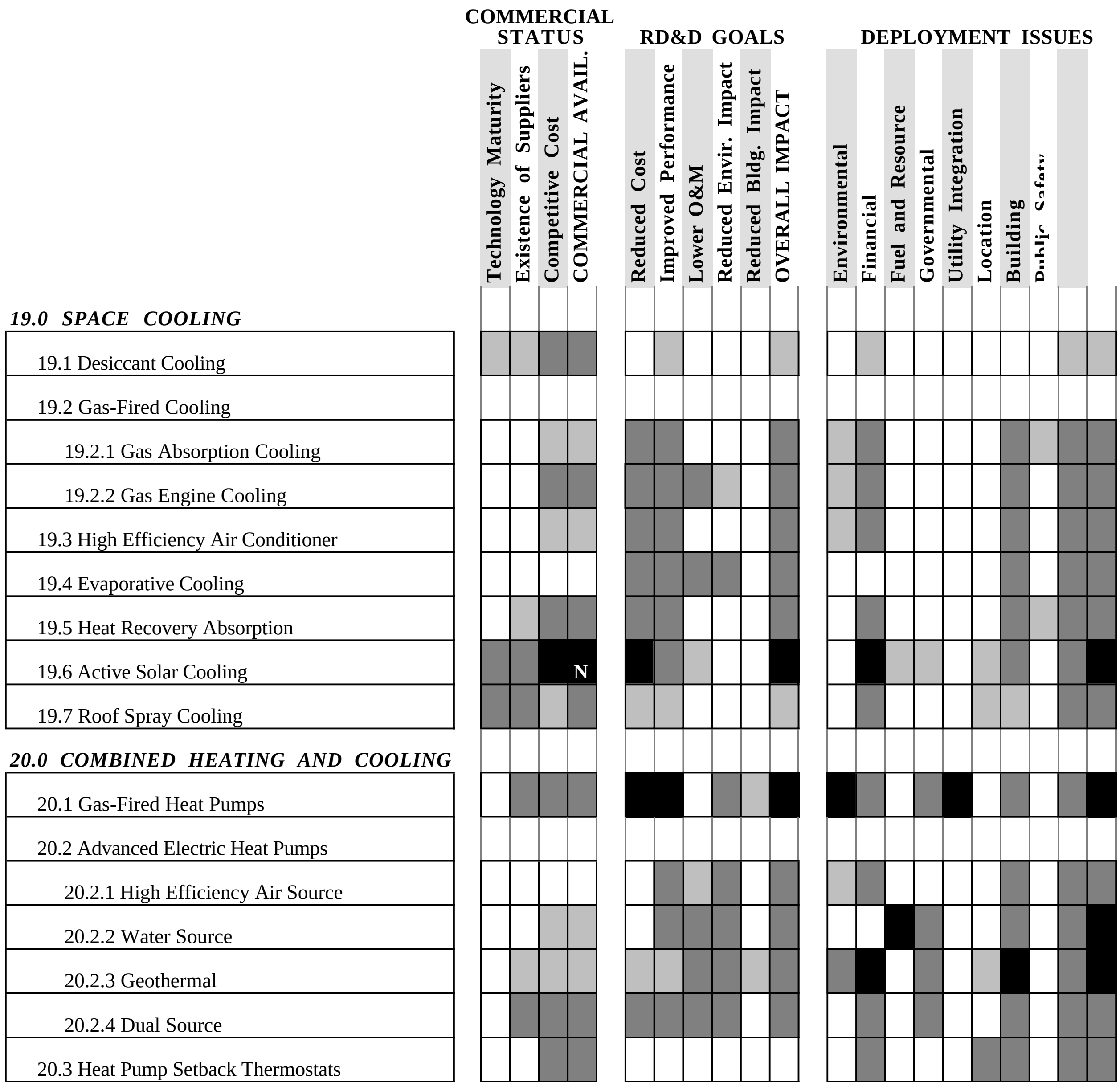
# *FIGURE 1: Technology Evaluation Matrix (continued)*

| | COMMERCIAL STATUS | | | | RD&D GOALS | | | | | | DEPLOYMENT ISSUES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technology Maturity | Existence of Suppliers | Competitive Cost | COMMERCIAL AVAIL. | Reduced Cost | Improved Performance | Lower O&M | Reduced Envir. Impact | Reduced Bldg. Impact | OVERALL IMPACT | Environmental | Financial | Fuel and Resource | Governmental | Utility Integration | Location | Building | Public Safety | | |
| ***15.0 FUEL CELLS*** | | | | | | | | | | | | | | | | | | | | |
| 15.1 Phosphoric Acid Utility-Scale Syst. | | | | N | | | | | | | | | | | | | | | | |
| 15.2 Molten Carbonate | | | | N | | | | | | | | | | | | | | | | |
| 15.3 Solid Oxide | | | | N | | | | | | | | | | | | | | | | |
| 15.4 Alkaline | | | | L | | | | | | | | | | | | | | | | |
| 15.5 Proton Exchange Membrane | | | | N | | | | | | | | | | | | | | | | |
| ***16.0 STORAGE SYSTEMS*** | | | | | | | | | | | | | | | | | | | | |
| 16.1 Pumped Hydroelectric | | | | | | | | | | | | | | | | | | | | |
| 16.1.1 Conventional Pumped Hydro | | | | | | | | | | | | | | | | | | | | |
| 16.1.2 Modular Pumped Hydro | | | | | | | | | | | | | | | | | | | | |
| 16.2 Compressed Air Energy Storage | | | | | | | | | | | | | | | | | | | | |
| 16.3 Utility-Scale Batteries | | | | | | | | | | | | | | | | | | | | |
| 16.4 Superconducting Magnetic Energy | | | | | | | | | | | | | | | | | | | | |

## *FIGURE 1: Technology Evaluation Matrix (continued)*

| | COMMERCIAL STATUS | | | | RD&D GOALS | | | | | | DEPLOYMENT ISSUES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technology Maturity | Existence of Suppliers | Competitive Cost | COMMERCIAL AVAIL. | Reduced Cost | Improved Performance | Lower O&M | Reduced Envir. Impact | Reduced Bldg. Impact | OVERALL IMPACT | Environmental | Financial | Fuel and Resource | Governmental | Utility Integration | Location | Building | Public Safety | | |
| ***17.0 WATER HEATING*** | | | | | | | | | | | | | | | | | | | | |
| 17.1 Pulse Combustion | | | | | | | | | | | | | | | | | | | | |
| 17.2 Condensing | | | | | | | | | | | | | | | | | | | | |
| 17.3 Radiant Burner Storage Type | | | | N | | | | | | | | | | | | | | | | |
| 17.4 Heat Pump | | | | | | | | | | | | | | | | | | | | |
| 17.5 Tankless | | | | | | | | | | | | | | | | | | | | |
| 17.6 Solar Water Heaters | | | | | | | | | | | | | | | | | | | | |
| 17.6.1 Passive Solar | | | | | | | | | | | | | | | | | | | | |
| 17.6.2 Active Solar | | | | | | | | | | | | | | | | | | | | |
| 17.7 ThermoPV Gas-Powered App. Equip. | | | | N | | | | | | | | | | | | | | | | |
| 17.8 Waste Heat Recovery | | | | | | | | | | | | | | | | | | | | |
| 17.9 Passive Hot Water Recovery Syst. | | | | | | | | | | | | | | | | | | | | |
| 17.10 Hot Water Demand System | | | | | | | | | | | | | | | | | | | | |
| 17.11 Hot Water Heater Vent Damper | | | | N | | | | | | | | | | | | | | | | |
| ***18.0 SPACE HEATING*** | | | | | | | | | | | | | | | | | | | | |
| 18.1 Condensing Furnaces | | | | | | | | | | | | | | | | | | | | |
| 18.1.1 Recuperating Furnaces | | | | | | | | | | | | | | | | | | | | |
| 18.1.2 Pulse Combustion Furnaces | | | | | | | | | | | | | | | | | | | | |
| 18.2 Heat Pipe Furnaces | | | | N | | | | | | | | | | | | | | | | |
| 18.3 Active Solar Heating | | | | I | | | | | | | | | | | | | | | | |

## *FIGURE 1: Technology Evaluation Matrix (continued)*




***KEY:*** ***COMMERCIAL STATUS: Degree each criteria is satisfied or degree of commercial availability***

Fully | Under Most Conditions | Under Limited or Rare Conditions | Not at All

***RD&D GOALS AND DEPLOYMENT ISSUES: Degree of impact for each goal or issue or overall impact***

No Impact | Minor Impact | Significant Impact | Potential "Show Stopper"

## *FIGURE 1: Technology Evaluation Matrix (continued)*

| | COMMERCIAL STATUS | | | | RD&D GOALS | | | | | | DEPLOYMENT ISSUES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technology Maturity | Existence of Suppliers | Competitive Cost | COMMERCIAL AVAIL. | Reduced Cost | Improved Performance | Lower O&M | Reduced Envir. Impact | Reduced Bldg. Impact | OVERALL IMPACT | Environmental | Financial | Fuel and Resource | Governmental | Utility Integration | Location | Building | Public Safety | | |
| 20.4 Integrated Appliances | | | | | | | | | | | | | | | | | | | | |
| 20.5 Heat Pipe Assisted Air Conditioning | | | | | | | | | | | | | | | | | | | | |
| 20.6 Passive Solar Heating and Cooling | | | | | | | | | | | | | | | | | | | | |
| ***21.0 BUILDING ENVELOPE TECHNOLOGIES (section not updated in 1995; ETSR 1992 impacts shown)*** | | | | | | | | | | | | | | | | | | | | |
| 21.1 Advanced Glazing Systems | | | | | | | | | | | | | | | | | | | | |
| 21.1.1 Films and Coatings | | | | | | | | | | | | | | | | | | | | |
| 21.1.2 High R-Value Windows | | | | | | | | | | | | | | | | | | | | |
| 21.1.2.1 Gas Filled Glazings | | | | | | | | | | | | | | | | | | | | |
| 21.1.2.2 Aerogel Glazings | | | | N | | | | | | | | | | | | | | | | |
| 21.1.2.3 Evacuated Glazings | | | | N | | | | | | | | | | | | | | | | |
| 21.1.2.4 Switchable Windows | | | | N | | | | | | | | | | | | | | | | |
| 21.2 Fenestration Control Systems | | | | | | | | | | | | | | | | | | | | |
| 21.3 Advanced Insulation | | | | | | | | | | | | | | | | | | | | |
| 21.4 Radiant Barriers | | | | | | | | | | | | | | | | | | | | |
| ***22.0 LIGHTING*** | | | | | | | | | | | | | | | | | | | | |
| 22.1 Energy Efficient Incandescent Lamps | | | | | | | | | | | | | | | | | | | | |
| 22.1.1 Reflector Lamps | | | | | | | | | | | | | | | | | | | | |
| 22.1.2 Tungsten-Halogen Lamps | | | | | | | | | | | | | | | | | | | | |

***KEY:*** ***COMMERCIAL STATUS: Degree each criteria is satisfied or degree of commercial availability***

Fully — Under Most Conditions — Under Limited or Rare Conditions — Not at All

***RD&D GOALS AND DEPLOYMENT ISSUES: Degree of impact for each goal or issue or overall impact***

No Impact — Minor Impact — Significant Impact — Potential "Show Stopper"

## *FIGURE 1: Technology Evaluation Matrix (continued)*

| | COMMERCIAL STATUS | | | | RD&D GOALS | | | | | | DEPLOYMENT ISSUES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technology Maturity | Existence of Suppliers | Competitive Cost | COMMERCIAL AVAIL. | Reduced Cost | Improved Performance | Lower O&M | Reduced Envir. Impact | Reduced Bldg. Impact | OVERALL IMPACT | Environmental | Financial | Fuel and Resource | Governmental | Utility Integration | Location | Building | Public Safety | | |
| 22.2 Fluorescent Lighting | | | | | | | | | | | | | | | | | | | | |
| 22.2.1 Compact Fluorescent Lamps | | | | | | | | | | | | | | | | | | | | |
| 22.2.2 Full-Size Fluorescent Lamps | | | | | | | | | | | | | | | | | | | | |
| 22.3 High Intensity Discharge (HID) Lighting | | | | | | | | | | | | | | | | | | | | |
| 22.3.1 Mercury Vapor Lamps | | | | | | | | | | | | | | | | | | | | |
| 22.3.2 Metal Halide Lamps | | | | | | | | | | | | | | | | | | | | |
| 22.3.3 High Pressure Sodium Lamps | | | | | | | | | | | | | | | | | | | | |
| 22.3.4 Low Pressure Sodium Lamps | | | | | | | | | | | | | | | | | | | | |
| 22.4 E-Lamps | | | | N | | | | | | | | | | | | | | | | |
| 22.5 Lighting Control Systems | | | | | | | | | | | | | | | | | | | | |
| 22.5.1 Daylighting | | | | | | | | | | | | | | | | | | | | |
| 22.5.2 Lumen Maintenance | | | | | | | | | | | | | | | | | | | | |
| 22.5.3 Occupancy Scheduling | | | | | | | | | | | | | | | | | | | | |
| 22.5.4 Fine Tuning | | | | | | | | | | | | | | | | | | | | |
| 22.5.5 Load Shedding | | | | | | | | | | | | | | | | | | | | |
| 22.6 Adv. Lighting Distribution Systems | | | | | | | | | | | | | | | | | | | | |
| 22.6.1 Light Pipes | | | | N | | | | | | | | | | | | | | | | |
| 22.6.2 Fiber Optics | | | | N | | | | | | | | | | | | | | | | |
| ***23.0 APPLIANCES (section not updated in 1995; ETSR 1992 impacts shown)*** | | | | | | | | | | | | | | | | | | | | |
| 23.1 Refrigerators | | | | | | | | | | | | | | | | | | | | |
| 23.1.1 Advanced Insulation | | | | N | | | | | | | | | | | | | | | | |
| 23.1.2 High Efficiency Refrigerators | | | | | | | | | | | | | | | | | | | | |

## *FIGURE 1: Technology Evaluation Matrix (continued)*

| | COMMERCIAL STATUS | | | | RD&D GOALS | | | | | | DEPLOYMENT ISSUES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technology Maturity | Existence of Suppliers | Competitive Cost | COMMERCIAL AVAIL. | Reduced Cost | Improved Performance | Lower O&M | Reduced Envir. Impact | Reduced Bldg. Impact | OVERALL IMPACT | Environmental | Financial | Fuel and Resource | Governmental | Utility Integration | Location | Building | Public Safety | | |
| 23.2 High Efficiency Cooking Appliances | | | | | | | | | | | | | | | | | | | | |
| 23.2.1 Residential Cooking Appliances | | | | | | | | | | | | | | | | | | | | |
| 23.2.1.1 Advanced Electric Cooktops | | | | | | | | | | | | | | | | | | | | |
| 23.2.1.2 Advanced Gas Ovens | | | | N | | | | | | | | | | | | | | | | |
| 23.2.1.3 Solar Cookers | | | | | | | | | | | | | | | | | | | | |
| 23.2.2 Comm. Cooking Appliances | | | | | | | | | | | | | | | | | | | | |
| 23.2.2.1 Advanced Fryers | | | | | | | | | | | | | | | | | | | | |
| 23.2.2.2 Advanced Burners | | | | N | | | | | | | | | | | | | | | | |
| 23.2.2.3 Advanced Griddles | | | | | | | | | | | | | | | | | | | | |
| 23.2.2.4 Advanced Ovens | | | | | | | | | | | | | | | | | | | | |
| 23.3 Advanced Dishwashers | | | | | | | | | | | | | | | | | | | | |
| 23.4 Advanced Clothes Washers | | | | | | | | | | | | | | | | | | | | |
| 23.5 Advanced Clothes Dryers | | | | | | | | | | | | | | | | | | | | |
| 23.6 Advanced Office Equipment | | | | | | | | | | | | | | | | | | | | |
| ***24.0 INDUSTRIAL APPLICATIONS (section not updated in 1995; ETSR 1992 impacts shown)*** | | | | | | | | | | | | | | | | | | | | |
| 24.1 Industrial Efficiency Improvement | | | | | | | | | | | | | | | | | | | | |
| 24.1.1 High Temperature Insulation | | | | | | | | | | | | | | | | | | | | |
| 24.1.2 Boiler & Steam System Improvements | | | | | | | | | | | | | | | | | | | | |
| 24.1.3 Waste Heat Recovery | | | | | | | | | | | | | | | | | | | | |
| 24.1.4 Pinch Analysis | | | | | | | | | | | | | | | | | | | | |
| 24.1.5 Advanced Industrial Controls | | | | | | | | | | | | | | | | | | | | |
| 24.1.6 Industrial Process Load Adjust. | | | | | | | | | | | | | | | | | | | | |

## *FIGURE 1: Technology Evaluation Matrix (continued)*

| | COMMERCIAL STATUS | | | | RD&D GOALS | | | | | | DEPLOYMENT ISSUES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Technology Maturity** | **Existence of Suppliers** | **Competitive Cost** | **COMMERCIAL AVAIL.** | **Reduced Cost** | **Improved Performance** | **Lower O&M** | **Reduced Envir. Impact** | **Reduced Bldg. Impact** | **OVERALL IMPACT** | **Environmental** | **Financial** | **Fuel and Resource** | **Governmental** | **Utility Integration** | **Location** | **Building** | **Public Safety** | | |
| 24.2 Alternate/Adv. Process Techs. | | | | | | | | | | | | | | | | | | | | |
| 24.2.1 Industrial Process Heat Pumps | | | ▓ | ▓ | ▓ | | | ░ | | ▓ | ░ | ▓ | | | | ▓ | ▓ | | ▓ | ▓ |
| 24.2.2 Freeze Concentration | | | | | ▓ | ▓ | | | | ▓ | | ▓ | | | | | | | ▓ | ▓ |
| 24.2.3 Membrane Processes | ░ | | ░ | ░ | | ▓ | | | | ▓ | ░ | ░ | | | | | | | | ░ |
| 24.2.4 Laser Processing | ▓ | | ▓ | ▓ | ▓ | ▓ | | | | ▓ | | ▓ | | | | | | | | ▓ |
| 24.2.5 Adv. Industrial Refrigeration | ░ | ░ | ░ | ░ | ▓ | ▓ | ▓ | | | ▓ | ░ | ▓ | | | | ░ | | | ▓ | ▓ |
| 24.2.6 Advanced Glass Processing | █ | █ | █ | █ N | ▓ | █ | ▓ | ▓ | | █ | | | | | | | | | ▓ | ▓ |
| 24.3 Adv. Heating, Drying and Curing | | | | | | | | | | | | | | | | | | | | |
| 24.3.1 Infrared Heating | | | ░ | ░ | | ░ | | | | ░ | | | | | | | | | ░ | ░ |
| 24.3.2 Microwave Heating | ░ | | ░ | ░ | ▓ | ▓ | | | | ▓ | | | | | | | ░ | | ░ | ░ |
| 24.3.3 Advanced Gas-Fired Heaters | █ | █ | █ | █ N | █ | █ | ▓ | █ | | █ | | ▓ | | | | | | ▓ | ▓ | ▓ |
| 24.3.4 Solar Industrial Process Heating | ▓ | ▓ | ▓ | ▓ | █ | ▓ | ░ | | | █ | ░ | █ | ░ | | | ░ | ░ | ░ | ▓ | █ |
| 24.4 Advanced Combustion | | | | | | | | | | | | | | | | | | | | |
| 24.4.1 Radiant Low NOx Tube Burners | | | ▓ | ▓ | ░ | ▓ | | ▓ | | ▓ | | ▓ | | | | | | | ▓ | ▓ |
| 24.4.2 Adv. Radiant Heat Transfer | █ | █ | █ | █ N | █ | █ | ▓ | ▓ | | █ | █ | █ | | | | | | | ▓ | █ |
| ***25.0 ADVANCED MOTORS*** | | | | | | | | | | | | | | | | | | | | |
| 25.1 Programmable DC Motors | ▓ | ▓ | ░ | ▓ | ▓ | ▓ | | | | ▓ | | ░ | | | | | ▓ | | ▓ | ▓ |
| 25.2 Variable Speed Drive AC Motors | | | | | ▓ | ▓ | | | | ▓ | | ░ | | | | | ▓ | | ▓ | ▓ |

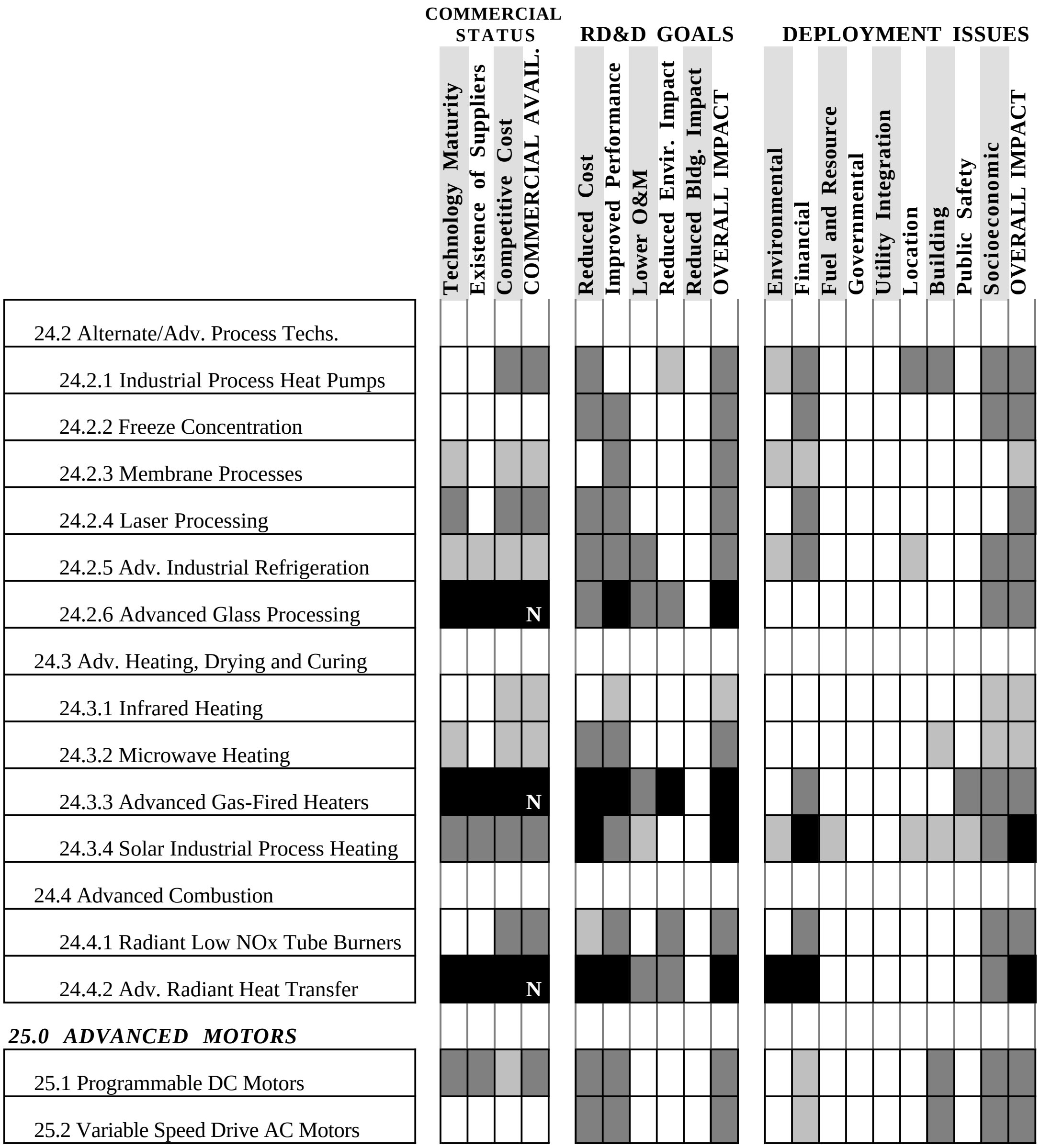
***KEY:*** ***COMMERCIAL STATUS: Degree each criteria is satisfied or degree of commercial availability***

□ Fully ░ Under Most Conditions ▓ Under Limited or Rare Conditions █ Not at All

***RD&D GOALS AND DEPLOYMENT ISSUES: Degree of impact for each goal or issue or overall impact***

□ No Impact ░ Minor Impact ▓ Significant Impact █ Potential "Show Stopper"

## *FIGURE 1: Technology Evaluation Matrix (continued)*



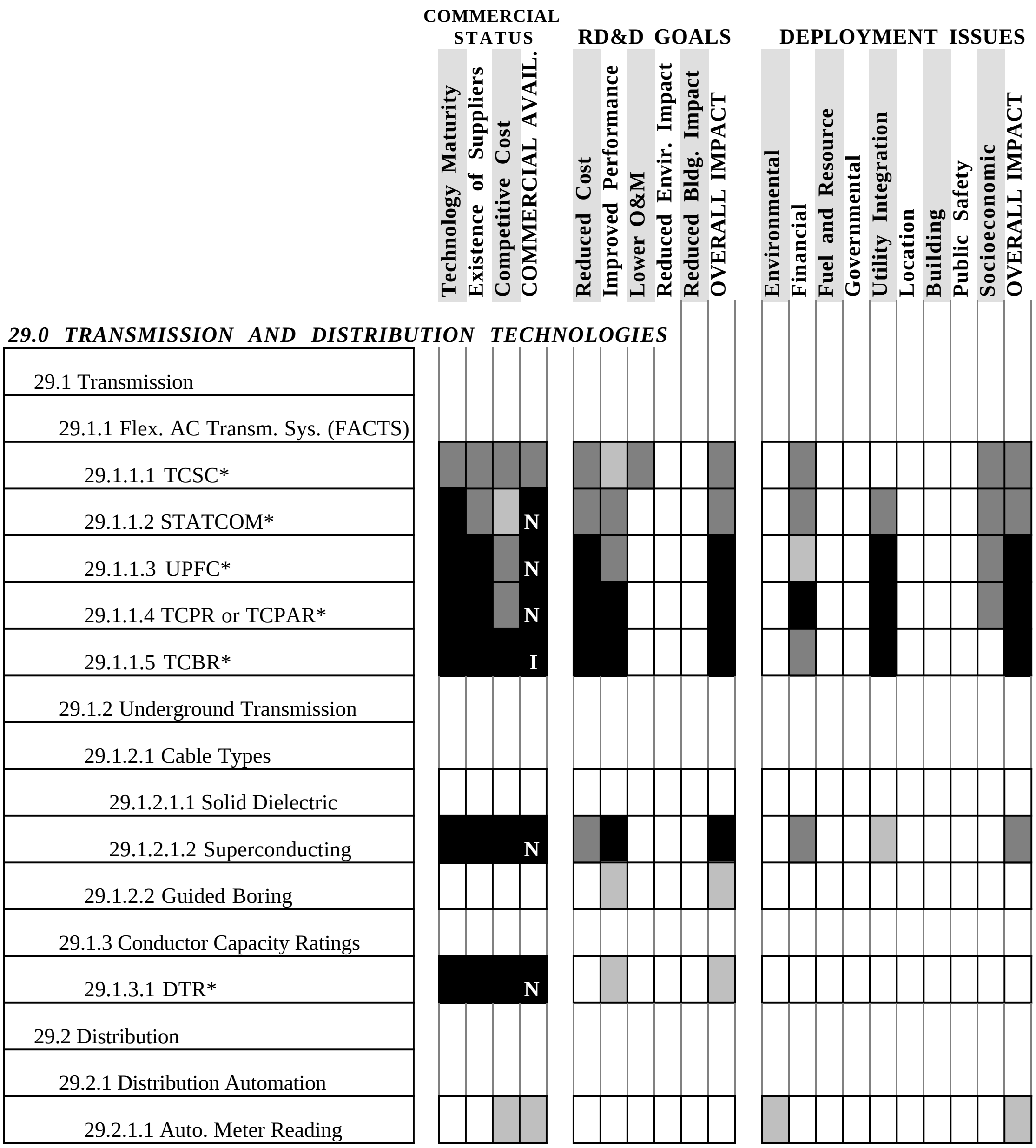

**KEY:** ***COMMERCIAL STATUS: Degree each criteria is satisfied or degree of commercial availability***

- Fully
- Under Most Conditions
- Under Limited or Rare Conditions
- Not at All

***RD&D GOALS AND DEPLOYMENT ISSUES: Degree of impact for each goal or issue or overall impact***

- No Impact
- Minor Impact
- Significant Impact
- Potential "Show Stopper"

## *FIGURE 1: Technology Evaluation Matrix (continued)*




***KEY:*** ***COMMERCIAL STATUS: Degree each criteria is satisfied or degree of commercial availability***

Fully | Under Most Conditions | Under Limited or Rare Conditions | Not at All

***RD&D GOALS AND DEPLOYMENT ISSUES: Degree of impact for each goal or issue or overall impact***

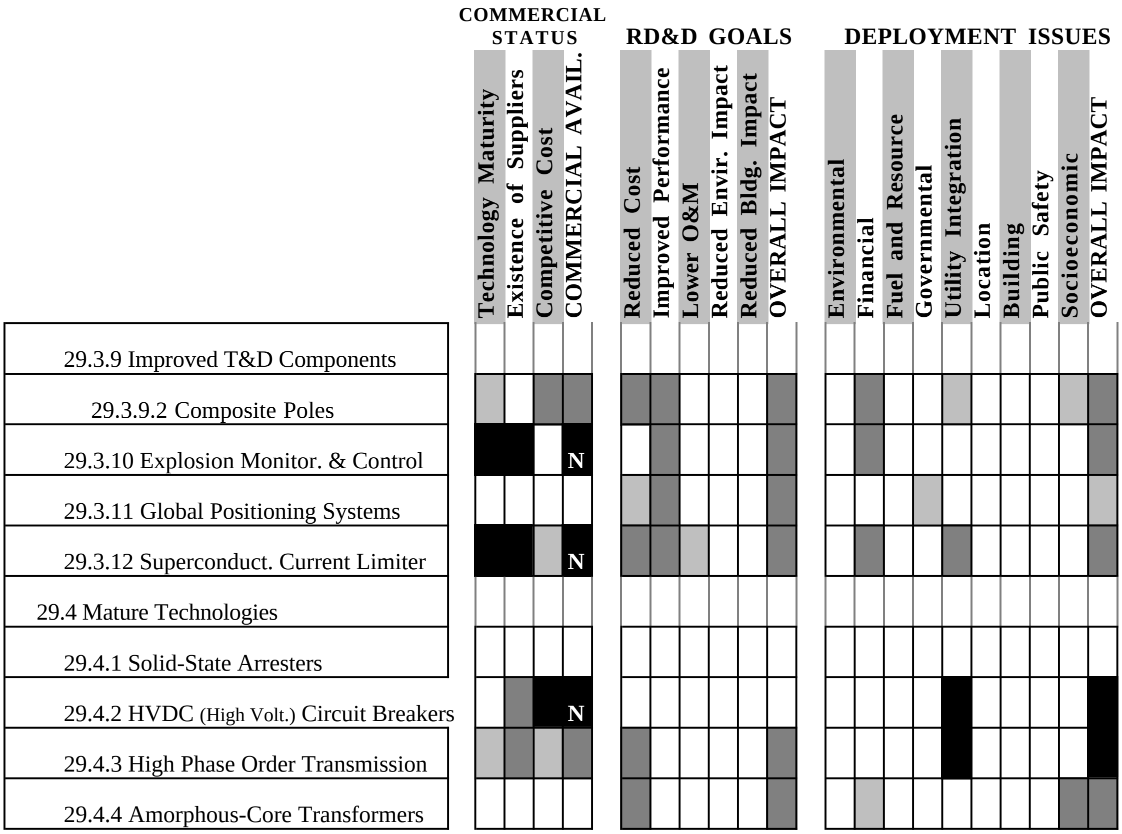
No Impact | Minor Impact | Significant Impact | Potential "Show Stopper"

## *FIGURE 1: Technology Evaluation Matrix (continued)*

| | COMMERCIAL STATUS | | | | RD&D GOALS | | | | | | DEPLOYMENT ISSUES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technology Maturity | Existence of Suppliers | Competitive Cost | COMMERCIAL AVAIL. | Reduced Cost | Improved Performance | Lower O&M | Reduced Envir. Impact | Reduced Bldg. Impact | OVERALL IMPACT | Environmental | Financial | Fuel and Resource | Governmental | Utility Integration | Location | Building | Public Safety | Socioeconomic | OVERALL IMPACT |
| 29.2.2 EMF Management* | | | | | | | | | | | | | | | | | | | | |
| 29.2.2.1 Magnetic Shielding | | | | | | | | | | | | | | | | | | | | |
| 29.2.2.2 EMF Design Guidelines | | | | I | | | | | | | | | | | | | | | | |
| 29.2.3 Power Quality Imp. Tools | | | | | | | | | | | | | | | | | | | | |
| 29.2.3.1 DSTATCOM* | | | | | | | | | | | | | | | | | | | | |
| 29.2.3.2 Dynamic Voltage Restorer | | | | | | | | | | | | | | | | | | | | |
| 29.2.3.3 Solid-State Circuit Breakers | | | | N | | | | | | | | | | | | | | | | |
| 29.3 T&D System Support | | | | | | | | | | | | | | | | | | | | |
| 29.3.1 AM/FM/GIS* | | | | | | | | | | | | | | | | | | | | |
| 29.3.2 Communication & Info. Techs. | | | | | | | | | | | | | | | | | | | | |
| 29.3.3 SCADA* | | | | | | | | | | | | | | | | | | | | |
| 29.3.4 Resource & Planning Tools | | | | | | | | | | | | | | | | | | | | |
| 29.3.4.1 Software Tools | | | | N | | | | | | | | | | | | | | | | |
| 29.3.4.2 Operation Tools | | | | | | | | | | | | | | | | | | | | |
| 29.3.4.2.1 UCA* | | | | | | | | | | | | | | | | | | | | |
| 29.3.4.2.1.1 ICCP* | | | | N | | | | | | | | | | | | | | | | |
| 29.3.5 Adv. Maintenance Strategies | | | | | | | | | | | | | | | | | | | | |
| 29.3.5.1 Reliability-Centered Maint. | | | | N | | | | | | | | | | | | | | | | |
| 29.3.5.2 Robotics | | | | N | | | | | | | | | | | | | | | | |
| 29.3.5.3 Live-Line Helicopter Use | | | | | | | | | | | | | | | | | | | | |
| 29.3.6 Ground-Penetrating Radar | | | | N | | | | | | | | | | | | | | | | |
| 29.3.7 Lightning Detection/Protection | | | | | | | | | | | | | | | | | | | | |
| 29.3.7.2 NLDN and FALLS* | | | | | | | | | | | | | | | | | | | | |
| 29.3.8 Severe Storm Detection | | | | | | | | | | | | | | | | | | | | |

* Acronyms are defined in Section 2.4 (pp. 32-35) of this report summary

## *FIGURE 1: Technology Evaluation Matrix (continued)*




***KEY: COMMERCIAL STATUS: Degree each criteria is satisfied or degree of commercial availability***

Fully | Under Most Conditions | Under Limited or Rare Conditions | Not at All

***RD&D GOALS AND DEPLOYMENT ISSUES: Degree of impact for each goal or issue or overall impact***

No Impact | Minor Impact | Significant Impact | Potential "Show Stopper"

### *3.2 Competitive Cost Analysis*

As indicated, the evaluation of cost competitiveness involved economic analyses comparing the cost of each energy technology with "benchmark" costs established for six ownership sectors involved in decisions to use energy technologies. A levelized cost[1] approach was selected as the most appropriate economic evaluation tool for this comparative analysis even though most ownership sectors do not use levelized costs in their economic decision-making. This was done so that policy determinations would be based on the most rational process for evaluating cost competitiveness. Due to analysis limitations, however, only the monetary costs (capital, fuel, operation and maintenance) associated with each technology were evaluated rather than full social costs that would include external costs (environmental, health and safety) and government subsidies (R&D support and tax incentives).

A detailed computer cash-flow model calculated an upper and lower bound for each ownership sector's benchmark costs. This model provides costs for both electricity in cents/kWh and fuel (thermal) energy in $/MMBtu (million Btu) depending on the type of energy generated or displaced. The resulting benchmark costs for appropriate electric generation and end-use technology ownership sectors are shown in Figures 2 and 3 respectively. These costs represent a range of acceptable costs that each generation ownership sector would pay for different types of energy production and each end-use technology ownership sector would pay for energy saved.

The types of energy production for electric generation ownership sectors are distinguished according to three general duty cycles (baseload, intermediate and peaking) and specific intermittent energy technologies (those that operate only when the resource is available, *e.g.*, wind, solar parabolic dish, solar parabolic trough, photovoltaics central station, ocean wave technology and storage systems).

The distinction among duty cycles is not absolute. The manner in which a power plant representing a specific technology is used depends not only on technology-specific performance characteristics, but also fuel costs, variable operation and maintenance costs, and the composition of the utility generating system. Certain intermittent technologies have the potential to operate even when the resource is not available because of storage (*e.g.*, solar central receiver) or because of hybrid operation (*e.g.*, solar parabolic trough with fossil fuel firing capability to provide thermal energy to a turbine when the sun is not shining). The analysis for intermittent technology costs calculated a weighted average of the costs for baseload, intermediate and peaking plants based on the percentage of intermittent technology output that occurred during these time periods.

The type of energy saved for end-use technologies is broken into fuel (thermal) and electricity. The resulting benchmark costs were then used as the basis for determining cost competitiveness for each energy technology.

[1] A levelized cost is the average cost over the lifetime of a facility with future costs discounted by the time value of money.

## *FIGURE 2: BENCHMARK LEVELIZED COSTS FOR ELECTRIC GENERATION TECHNOLOGIES*
### *(acceptable costs in cents/kWh in constant 1993$)*

| | *OWNERSHIP SECTOR* | | |
|---|---|---|---|
| ***TYPE OF ENERGY PRODUCTION*** | INVESTOR OWNED UTILITY | MUNICIPAL UTILITY | NON-UTILITY GENERATOR |
| Baseload | 3.9 - 4.4 | 3.5 - 3.9 | 3.9 - 4.4 |
| Intermediate | 5.4 - 7.8 | 4.4 - 6.0 | 5.4 - 7.8 |
| Peaking | 15.2 - 15.4 | 10.8 - 11.1 | 15.2 - 15.4 |
| Intermittent | | | |
| Wind | 6.0 - 7.0 | 4.8 - 5.5 | 6.0 - 7.0 |
| Solar Parabolic Dish (Dist. App.) | 11.1 - 12.2 | 8.1 - 8.9 | 11.1 - 12.2 |
| PV Central Station | 11.1 - 12.2 | 8.1 - 8.9 | 11.1 - 12.2 |
| Ocean Wave Energy | 8.1 - 9.2 | not used | not used |
| Storage Systems | 15.2 - 15.4 | 10.8 - 11.1 | not used |

Benchmark levelized costs are derived using the following assumptions:

1. For Investor Owned and Municipal Utilities, the values listed in the table are based upon the cost of conventional natural gas fueled technology (combined cycles and combustion turbines).

2. For Non-Utility Generators, the values listed in the table are assumed the same as Investor Owned Utilities since projects would be put in place under a bidding process competing with Investor Owned Utility identified deferable resources.

3. For Intermittent technologies, the following peak/mid-peak/off-peak percentage load profiles were used: wind 15%/27%/58%; solar parabolic dish (distributed application) 59%/38%/3%; photovoltaics central station 59%/38%/3%; ocean wave energy 33%/33%/34%; and storage systems 0%/0%/100%.

4. Costs are levelized over a typical lifetime (usually 30 years) beginning in 2000.

***FIGURE 3: BENCHMARK LEVELIZED COSTS FOR END-USE TECHNOLOGIES***
***(acceptable costs in cents/kWh or $/MMBtu in constant 1993$)***

| | ***OWNERSHIP SECTOR*** | | |
|---|---|---|---|
| ***FORM OF ENERGY SAVED*** | INDUSTRIAL | COMMERCIAL | RESIDENTIAL |
| Fuel (Thermal) ($/MMBtu) | not used | 5.4 - 6.1 | 5.4 - 5.9 |
| Electricity (cents/kWh) | not used | 8.8 - 9.8 | 10.0 - 11.1 |

Benchmark levelized costs are derived using the following assumptions:

1. The values listed in the table are based upon the retail cost of purchased natural gas or electricity.

2. All costs are in constant 1993 dollars, levelized over typical lifetimes (10 years for low case and 20 years for high case) and beginning in 1995.

The bases for determining benchmark costs for each ownership sector were as follows:

- **Investor-Owned Utilities and Municipal Utilities** use a conventional combined cycle plant for baseload and intermediate power and combustion turbine for peaking power because these are likely technologies to be used for these duty cycles.

- **Non-Utility Generators** use the cost of natural gas-fired combined cycle plant for baseload power.

- **Industrial, Commercial, and Residential Users** use the average statewide retail utility rates because they represent the cost of energy saved.

The ownership of generation assets is changing because of deregulation. Utilities are planning to divest from generating assets, and almost all the future generation assets are likely to be acquired from private power developers. Consequently, the debt/equity ratios, cost of capital, and some other parameters affecting the levelized costs have changed. Although analyses in this report are still based on six ownership structures used in previous years, the cost of capital and debt/equity ratios appropriate for each ownership category incorporates changes to reflect increased risk premiums demanded by the financial markets to account for uncertainty.

As part of the cost analyses, aggregate data representative of the cost of capital for the six ownership sectors were collected. This cost of capital data was used in the computer model to discount future expenses in the levelizing process. Once benchmark costs were established, the levelized costs of energy produced or saved for each energy technology were calculated with the same computer cash-flow model.

Results of the levelized cost analyses are shown graphically for electric generation technologies in Figures 4 through 9 and for end-use technologies in Figures 10 through 13. In all of these figures, specific energy technology costs are compared with costs for each ownership sector. In addition, the costs calculated by the levelized cash-flow model are listed in Tables 4 through 9 for electric generation technologies and in Tables 10 through 13 for end-use technologies. The figures and tables group commercially available and not commercially available technologies separately.

Noncommercial technology analyses are typically based on estimated future costs which can have high levels of uncertainty. These estimated future costs frequently are goals that must be achieved if the technology is to be cost competitive. The estimates may or may not be based on manufacturing and marketing cost analyses.

In all cases, the absolute and relative levelized cost evaluations should be used with care. Capital and operation and maintenance cost estimates in the literature are made with varying degrees of sophistication and with different sets of assumptions. The cost estimates found in the literature for many technologies could not be reduced to a common basis by Energy Commission staff.

A single point was considered unrealistic for both hurdle rates and technology levelized cost estimates due to the wide range of uncertainty in regard to economic parameters appropriate to different ownership sectors and energy technologies. As a result, the levelized costs calculated for both the economic decision matrix and each energy technology were bracketed by using a range of high-case and low-case technical and financial input parameters.

All costs from the computer analysis are in “constant” and “nominal” dollars referenced to a 1993 base year. Constant dollars exclude inflation but include real escalation (escalation above or below inflation) while nominal dollars include real escalation and inflation. In both cases, costs are escalated and levelized from the first year of operation over the life of the technology.

The levelized cost analysis for each generation technology evaluates the total capital, operation and maintenance, and fuel costs over the life of the plant. The resulting levelized costs can be compared among different generation technologies and the benchmark cost to determine relative cost competitiveness.

Final determinations on cost competitiveness were based on the extent to which each energy technology cost satisfied at least one appropriate ownership sector’s cost. In some cases where an energy technology levelized cost was higher than any ownership sector benchmark cost, the technology may be considered cost competitive under limited conditions if it historically had been cost competitive.

The economics of some generation technologies (*e.g.*, cogeneration, distributed generation) are quite site-specific, and it is often difficult to provide a representative cost range. In order to reflect the cost components, cost structure, and load parameters involved in calculating levelized costs of such technologies, the report includes sample assumptions and calculations for the levelized cost.

The levelized cost analysis for each end-use technology typically determines the cost of energy saved (cents/kWh of electricity or $/MMBtu of natural gas) compared to a baseline conventional technology. The baseline technology is either the minimum performing technology allowed by energy code (California Title 24) or the most commonly used technology where not regulated by energy code. Since the advanced technologies provide energy savings, there is no fuel component associated with the incremental cost for the advanced technology. There is, however, an incremental capital cost and often a differential operation and maintenance cost.

For some end-use technologies, the levelized cost is a negative number. In these cases, the negative value from reduced operation and maintenance costs and energy savings exceeds the incremental capital cost for the technology. As an example, energy efficient lighting fixtures use not only fewer lamps than conventional fixtures, but lamps that last longer as well. This results in much lower maintenance costs to purchase and install lamps over the lifetime of the advanced fixture as well as in substantial energy savings.

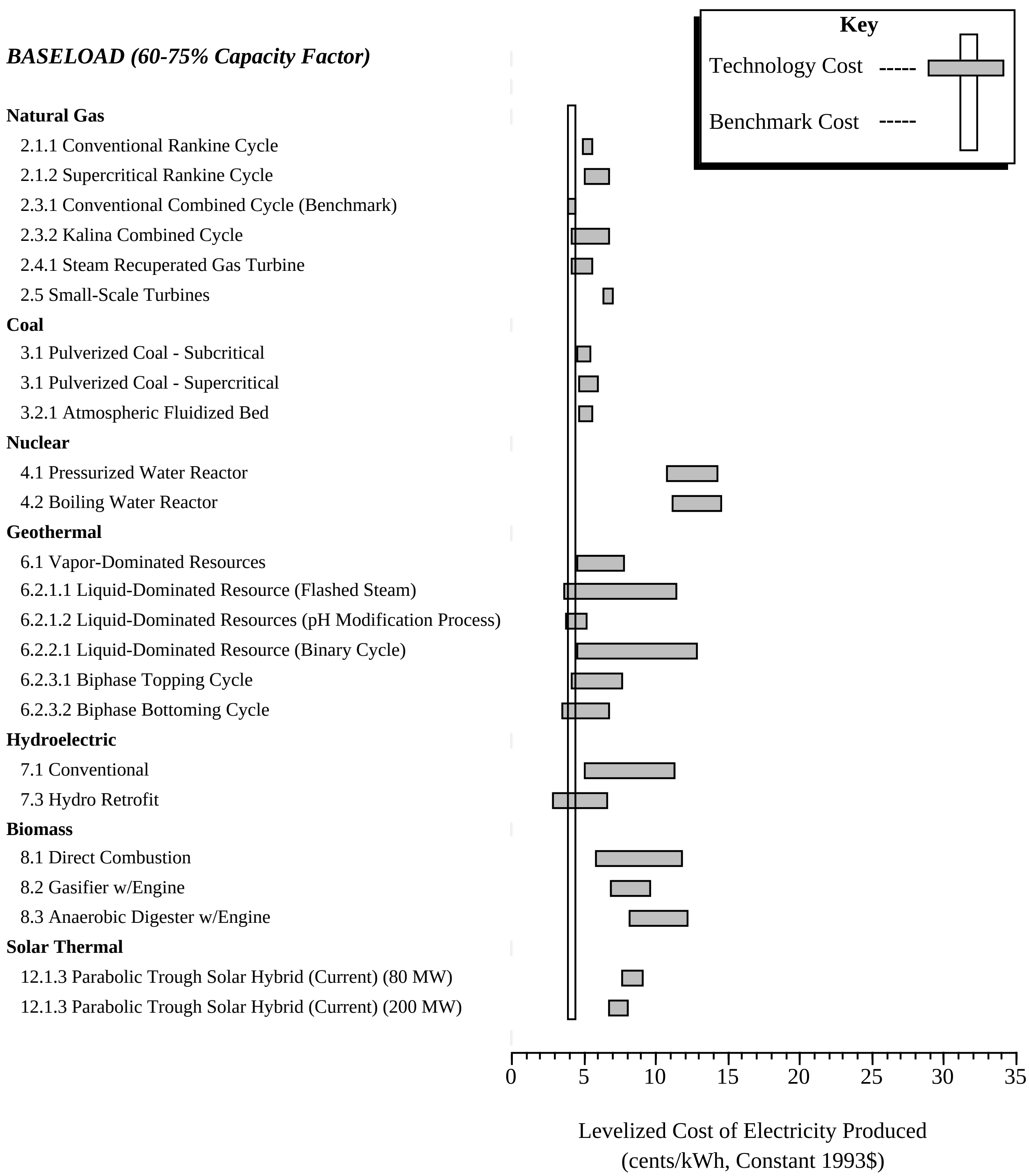
Cost competitiveness is determined for each end-use technology based on the levelized cost for each kWh or MMBtu purchased. If the levelized cost of the advanced end-use technology is lower than the benchmark energy cost, the end-user is effectively paying a lower rate for energy that makes the technology cost competitive.

The levelized cost of an advanced end-use technology can be also compared to the levelized costs of generation technologies in order to approximate the relative system-wide cost impact. This first requires, however, an assessment of the load factor (percentage of energy use during baseload, intermediate, and peak energy demand periods) for each end-use technology to allow appropriate comparisons to baseload, intermediate, or peaking technologies. End-use technology load factors are not provided in this ***ETSR***.

Note that levelized cost analyses were not performed for certain technologies in the ***ETSR*** because they were not suited to the constraints of the computer model or because necessary model input data were not available. In these cases, cost competitiveness determinations were assessed qualitatively based on expert opinion and information available from reference sources.

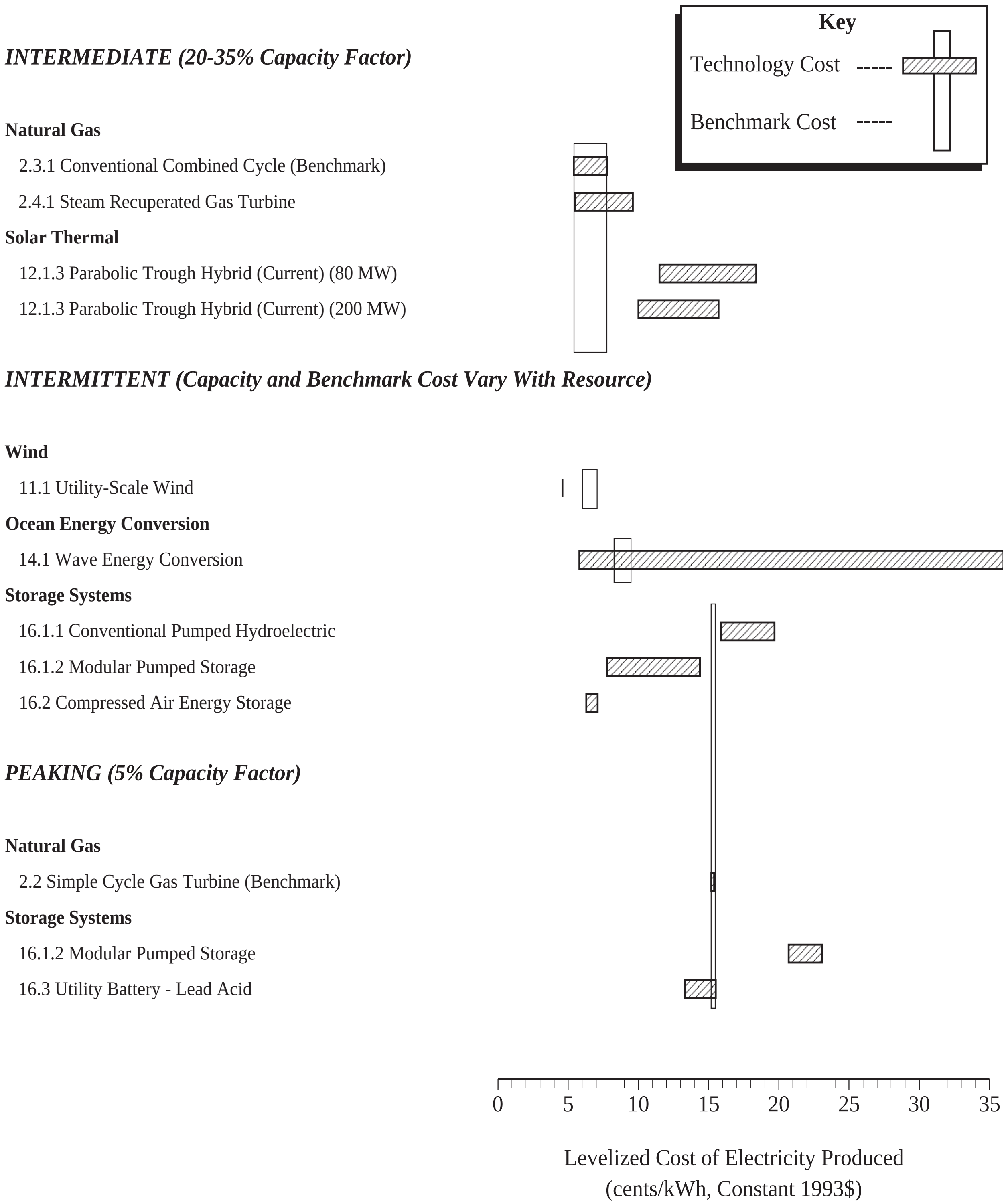
## FIGURE 4: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Commercially Available Electricity Generation Technologies**
**Utility (IOU) Ownership**



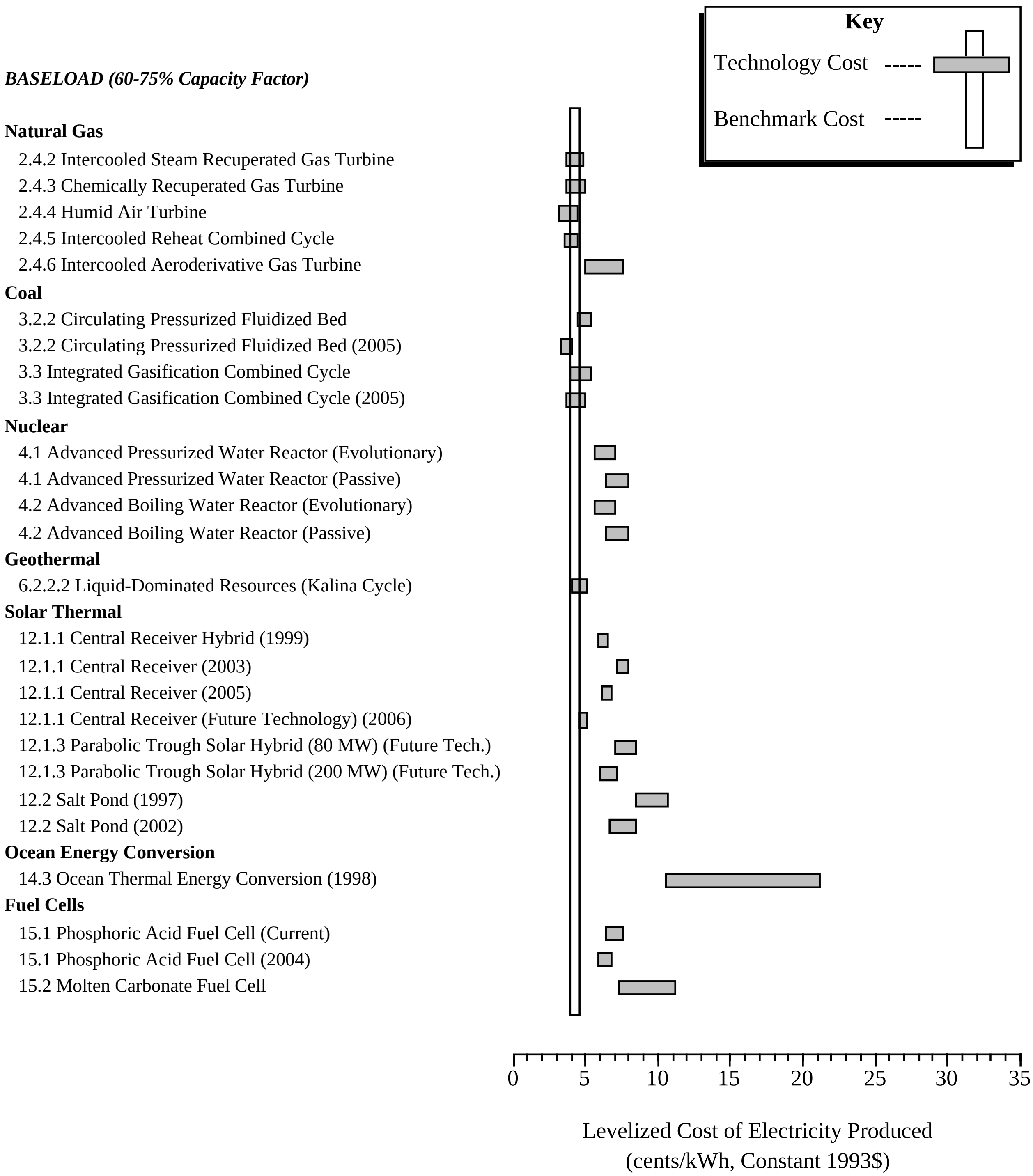
# FIGURE 4: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Commercially Available Electricity Generation Technologies**
**Utility (IOU) Ownership (continued)**



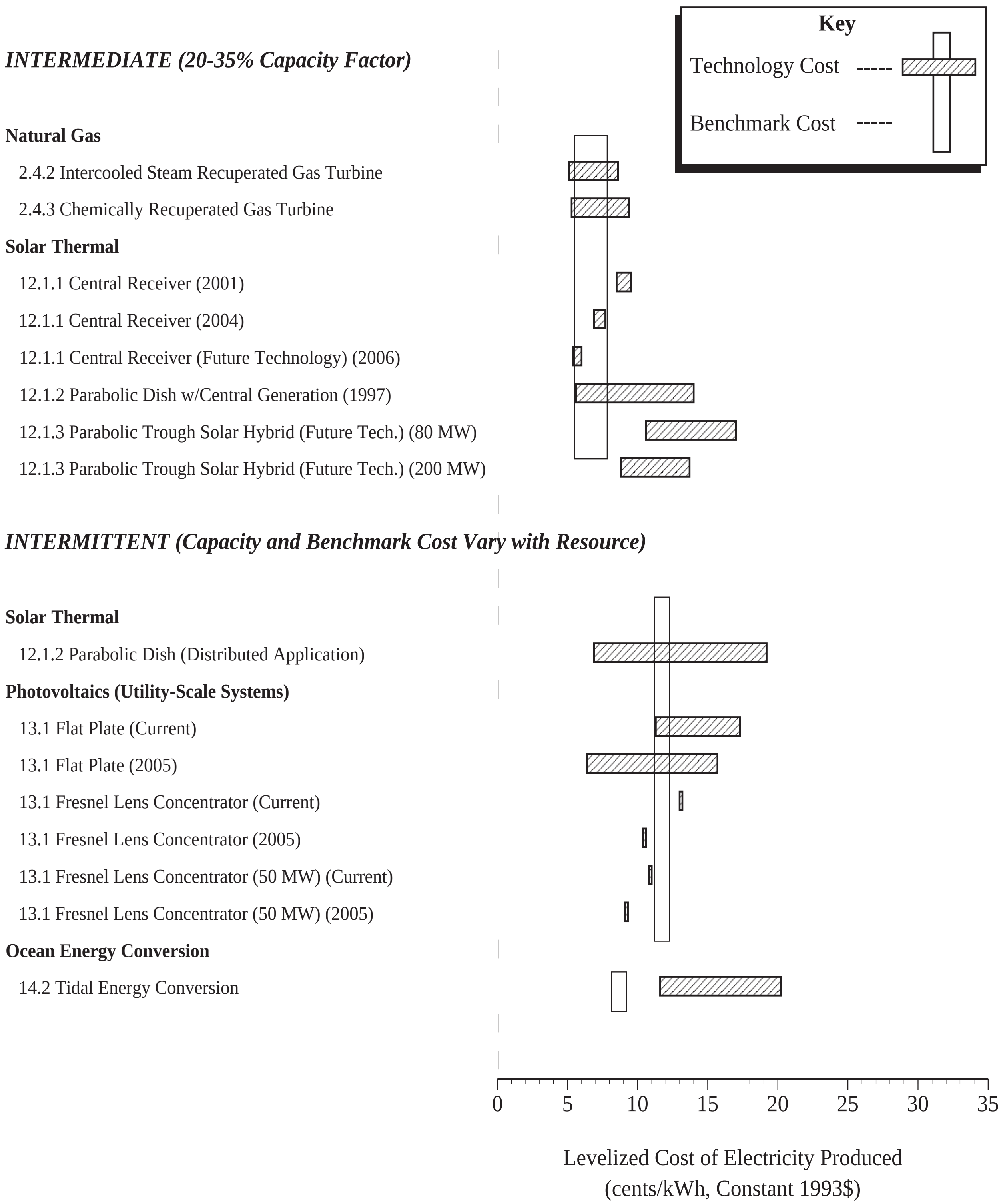
## FIGURE 5: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Electricity Generation Technologies NOT Commercially Available**
**Utility (IOU) Ownership**



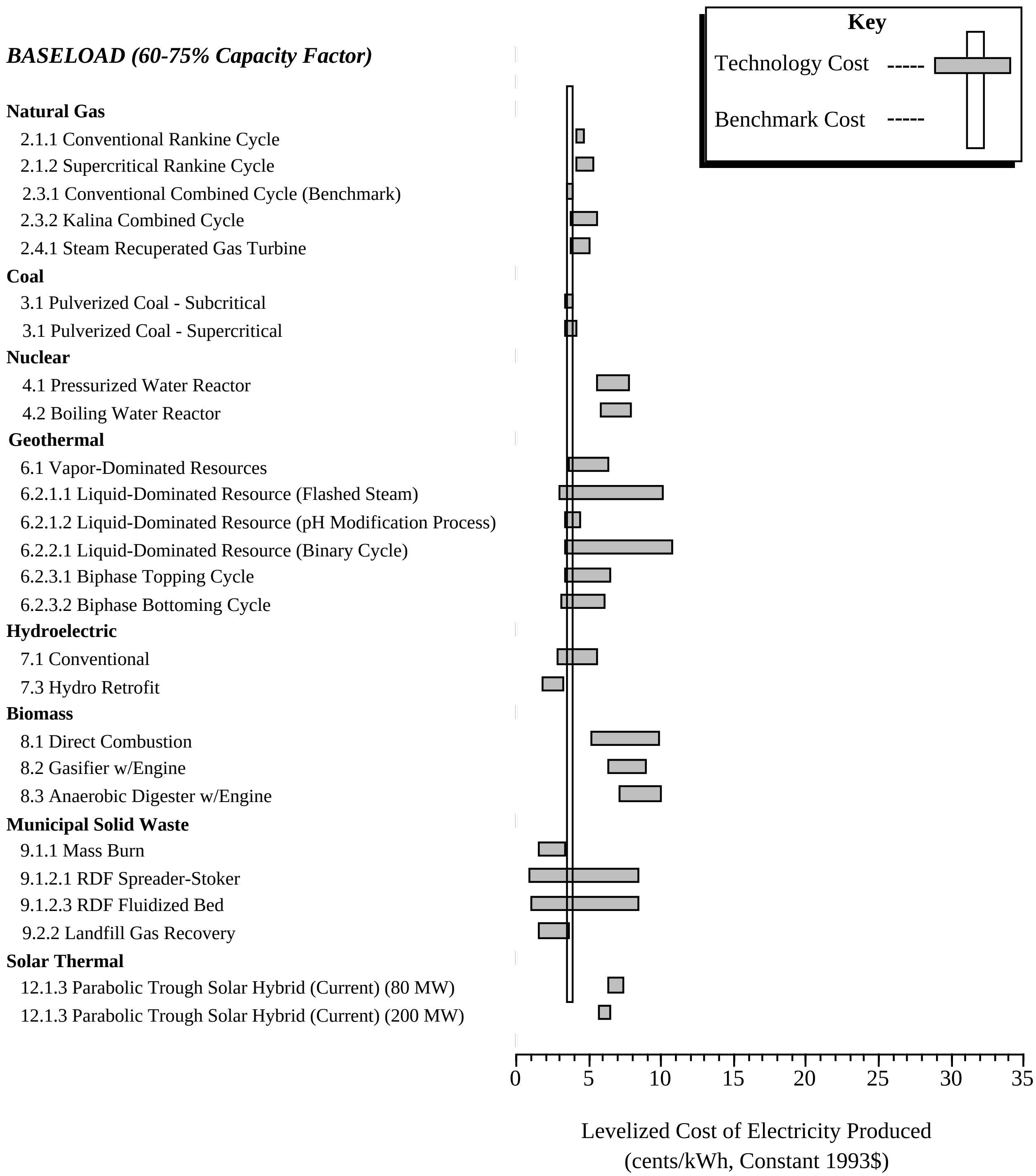
## FIGURE 5: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Electricity Generation Technologies NOT Commercially Available**
**Utility (IOU) Ownership (continued)**



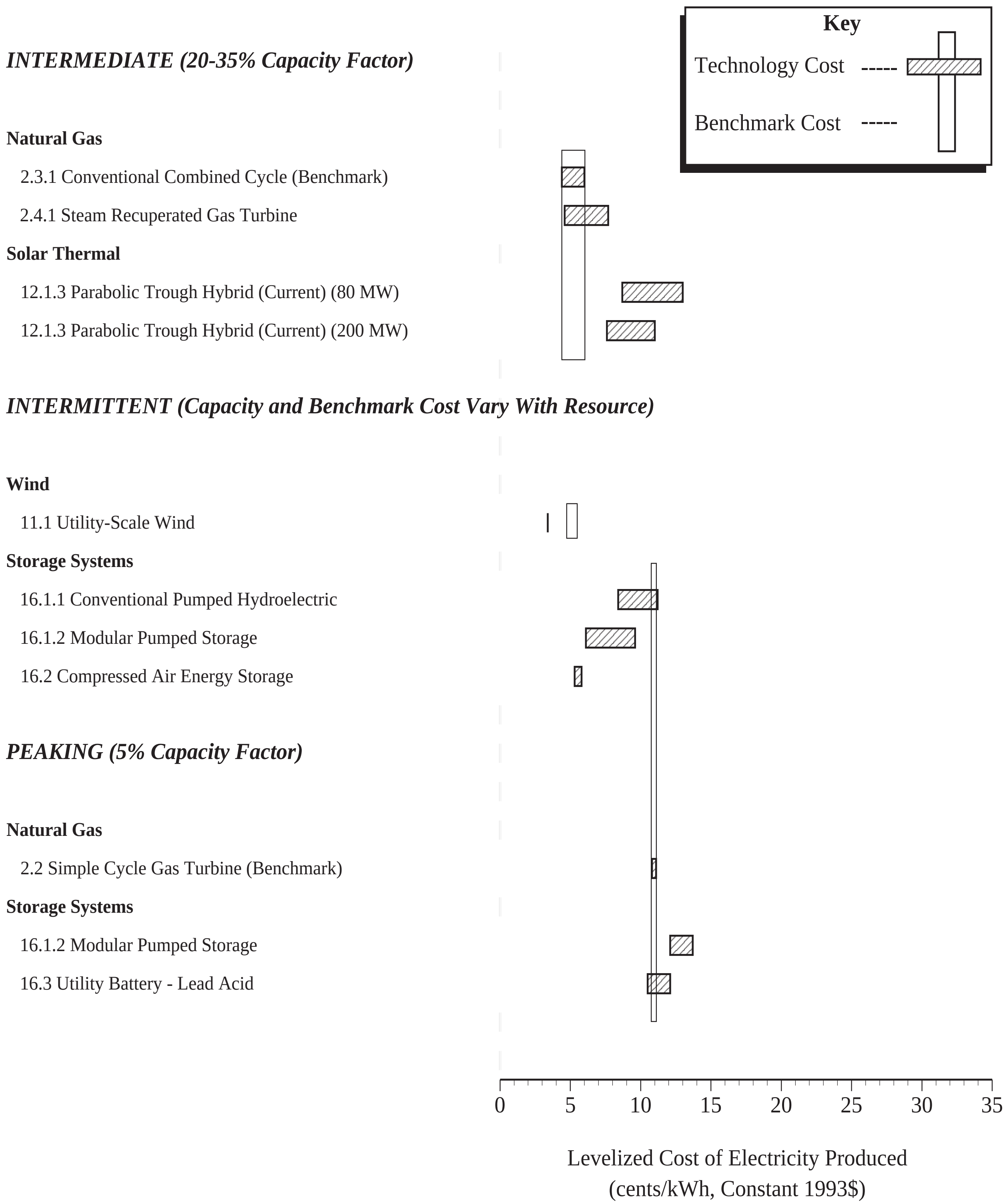
# FIGURE 6: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Commercially Available Electricity Generation Technologies**
**Municipal Utility (Government) Ownership**



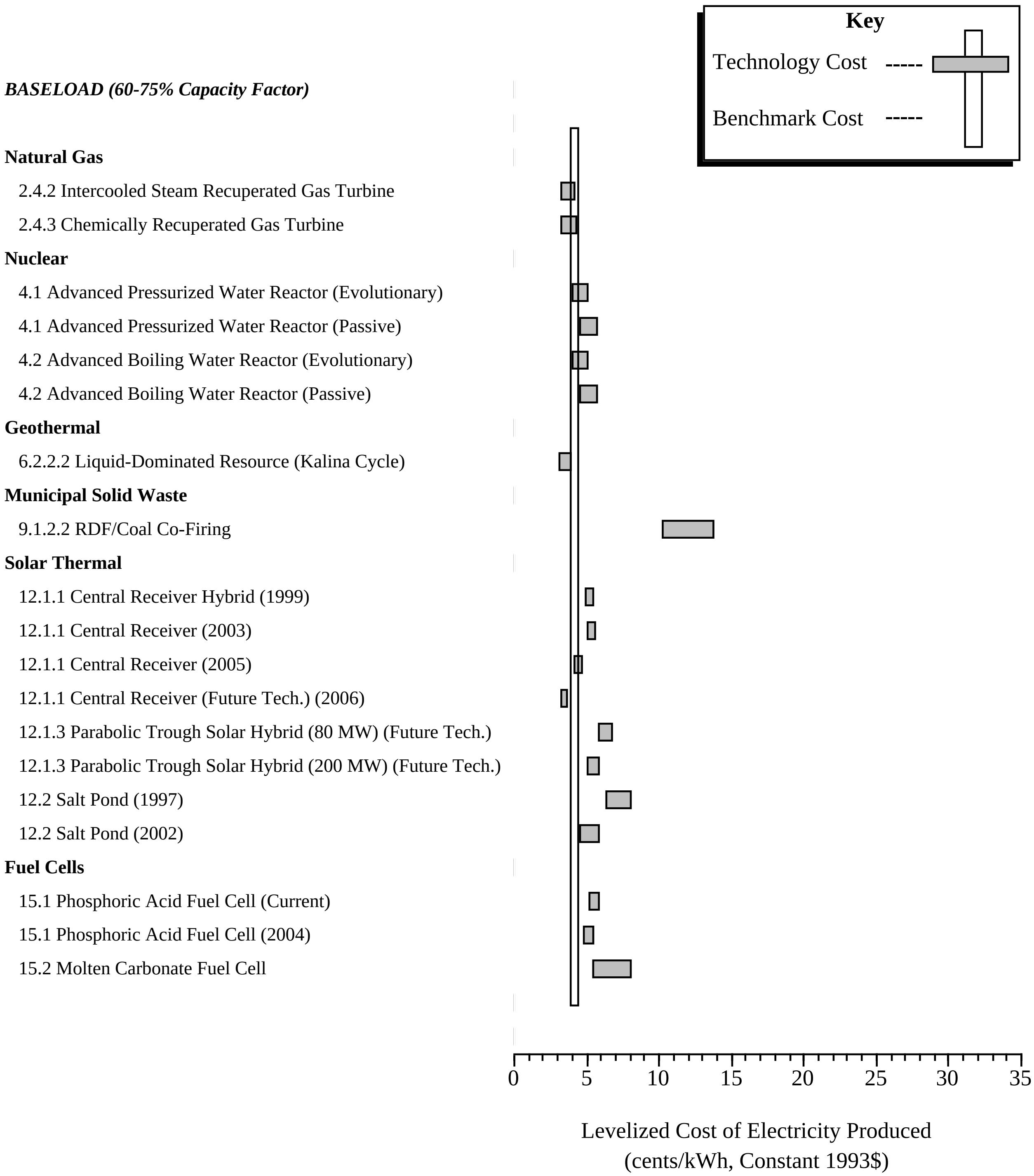
## FIGURE 6: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Commercially Available Electricity Generation Technologies**
**Municipal Utility (Government) Ownership (continued)**



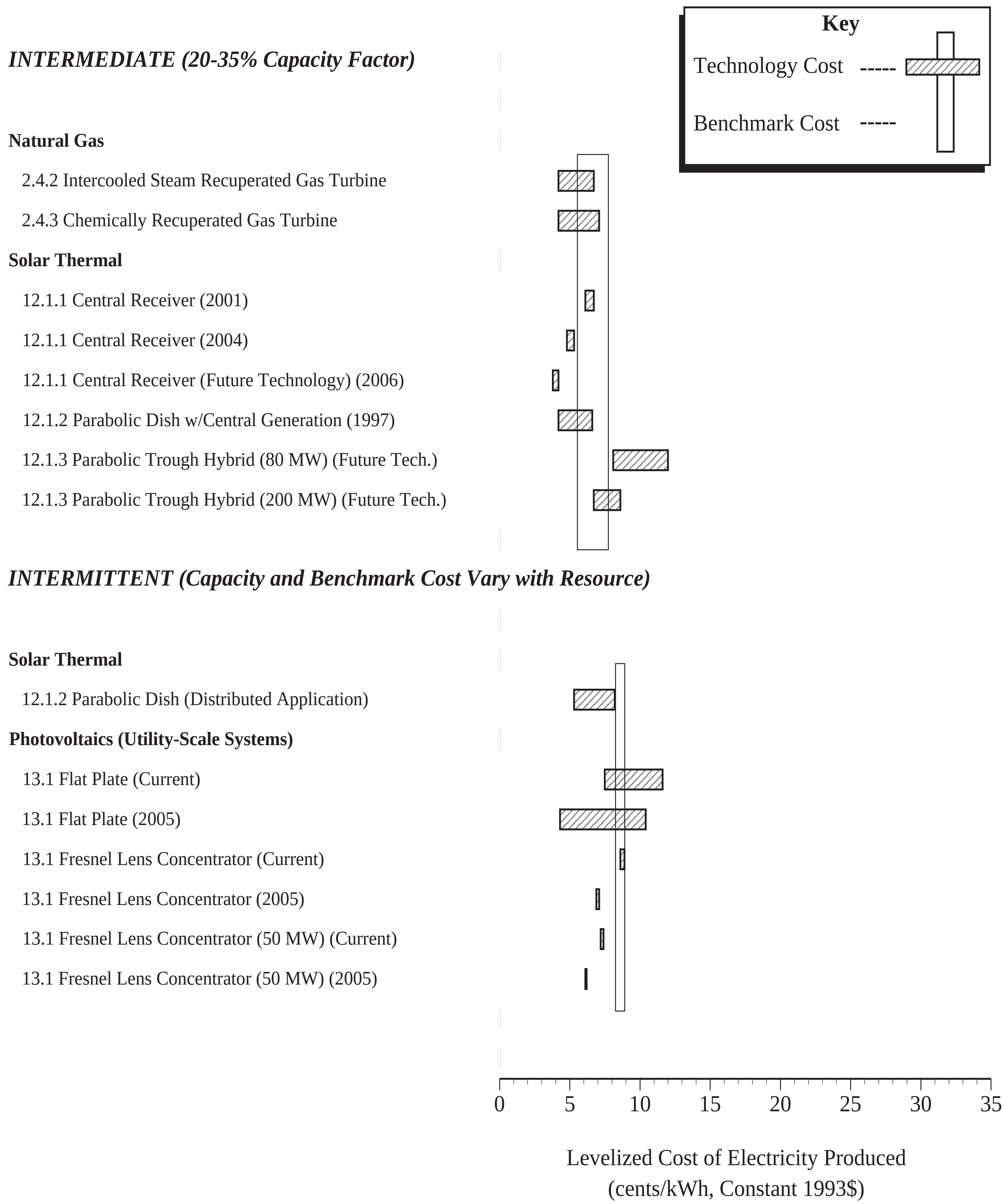
## FIGURE 7: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Electricity Generation Technologies NOT Commercially Available**
**Municipal Utility (Government) Ownership**



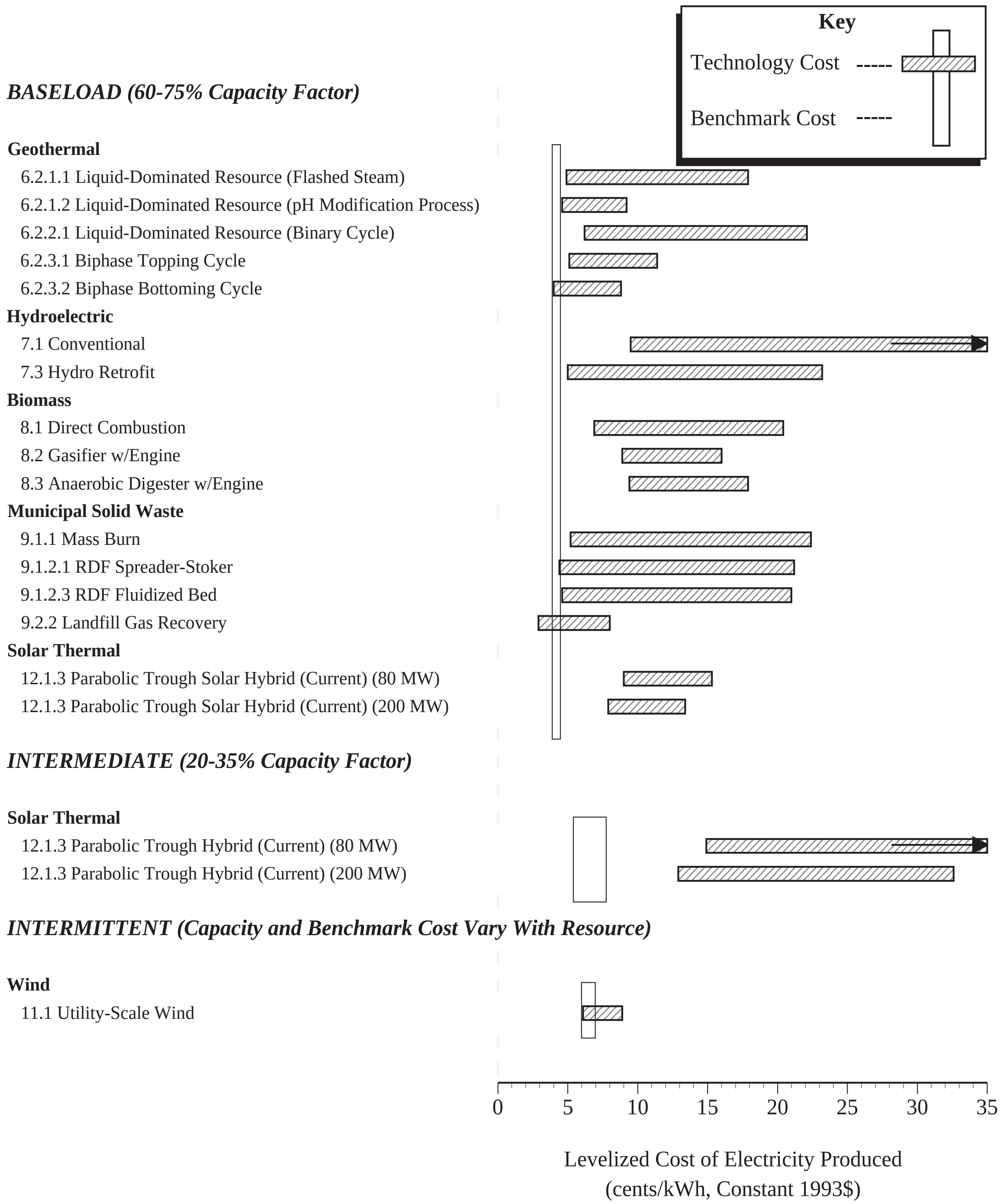
## FIGURE 7: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Electricity Generation Technologies NOT Commercially Available**
**Municipal Utility (Government) Ownership (continued)**



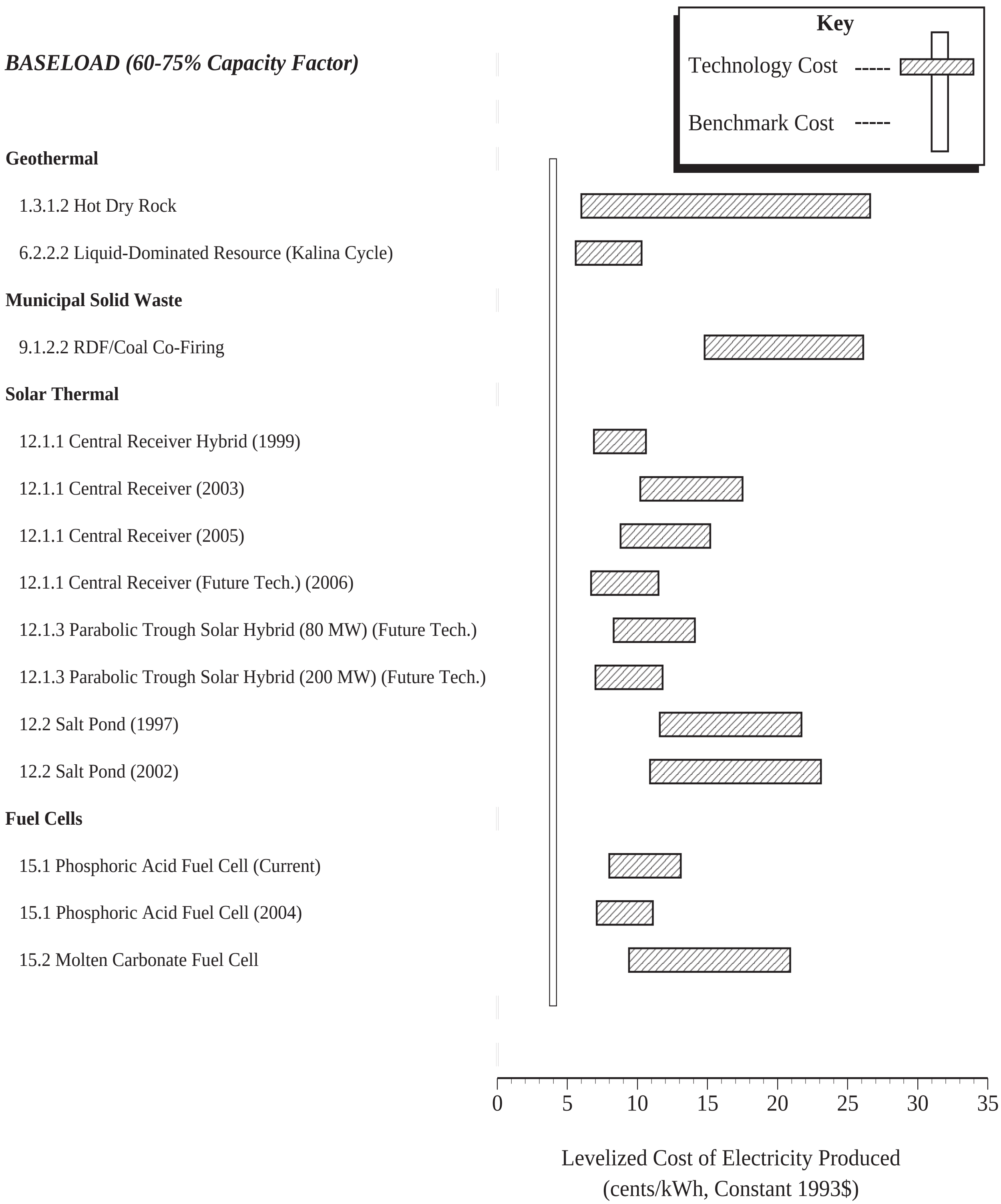
## FIGURE 8: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Commercially Available Electricity Generation Technologies**
**Non-Utility Generator (NUG) Ownership**



## FIGURE 9: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Electricity Generation Technologies NOT Commercially Available**
**Non-Utility Generator (NUG) Ownership**



## FIGURE 9: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Electricity Generation NOT Commercially Available Technologies**
**Non-Utility Generator (NUG) Ownership (continued)**

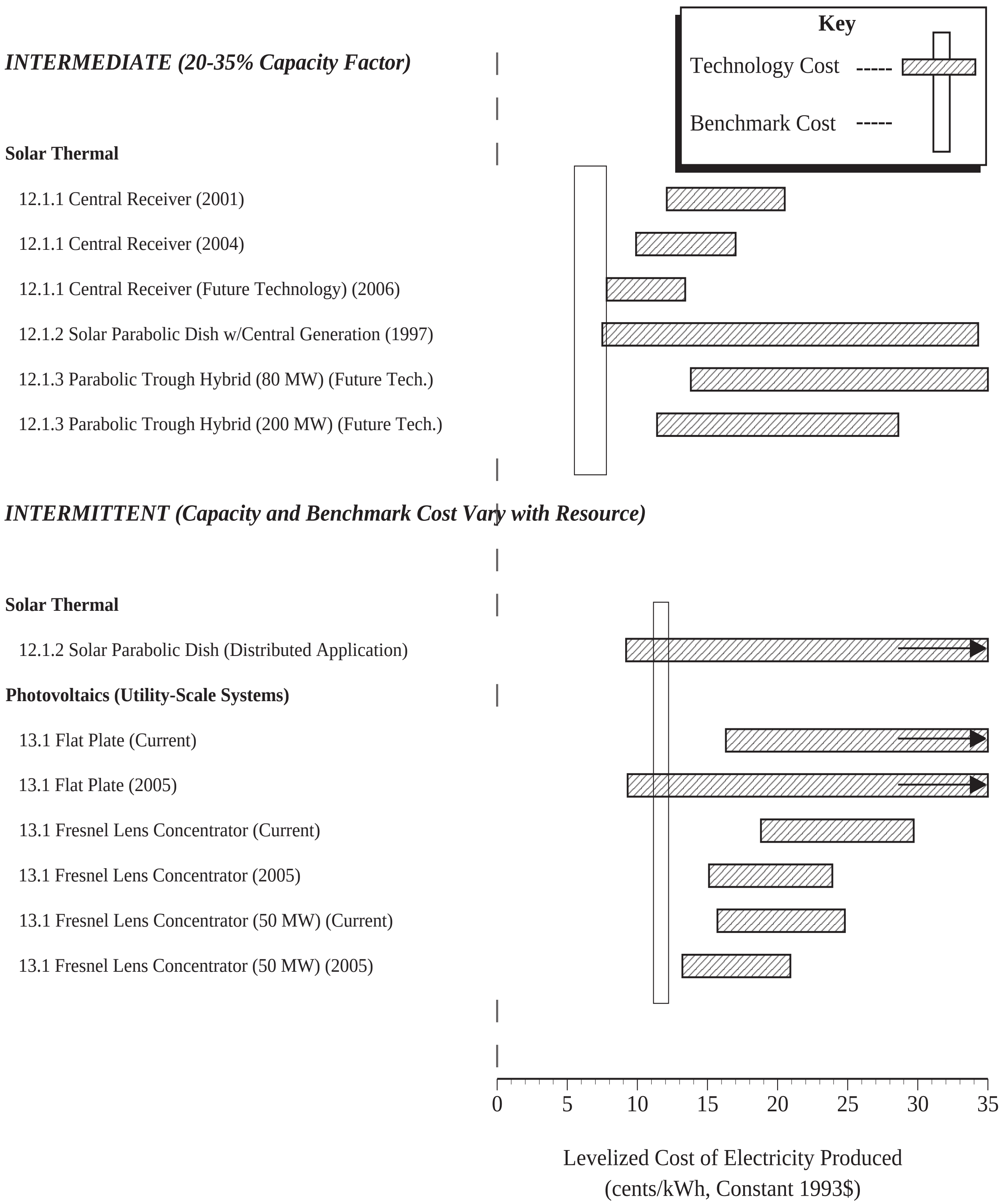


**TABLE 4: LEVELIZED COST ANALYSIS RESULTS**
**Commercially Available Electricity Generation Technologies**
**Utility (IOU) Ownership**

| | | | *1993 Reference Year Cents/kWh* | |
|---|---|---|---|---|
| | | | ***Constant $*** | ***Nominal $*** |
| ***BASELOAD (60-75% Capacity Factor)*** | | **Benchmark:** | ***3.9 - 4.4*** | |
| | ***Natural Gas*** | | | |
| 2.1.1 | Conventional Rankine Cycle | | 4.9 - 5.6 | 6.6 - 7.6 |
| 2.1.2 | Supercritical Rankine Cycle | | 5.1 - 6.7 | 6.8 - 9.0 |
| 2.3.1 | Conventional Combined Cycle (Benchmark) | | 3.9 - 4.4 | 5.3 - 6.0 |
| 2.3.2 | Kalina Combined Cycle | | 4.2 - 6.8 | 5.7 - 9.1 |
| 2.4.1 | Steam Recuperated Gas Turbine | | 4.1 - 5.6 | 5.6 - 7.7 |
| 2.5 | Small-Scale Turbines | | 6.3 - 7.0 | 7.8 - 8.7 |
| | ***Coal*** | | | |
| 3.1 | Pulverized Coal - Subcritical | | 4.6 - 5.5 | 5.9 - 7.1 |
| 3.1 | Pulverized Coal - Supercritical | | 4.7 - 6.0 | 6.1 - 7.7 |
| 3.2.1 | Atmospheric Fluidized Bed | | 4.7 - 5.6 | 6.2 - 7.4 |
| | ***Nuclear*** | | | |
| 4.1 | Pressurized Water Reactor | | 10.8 - 14.3 | 11.4 - 15.3 |
| 4.2 | Boiling Water Reactor | | 11.1 - 14.5 | 11.7 - 15.6 |
| | ***Geothermal*** | | | |
| 6.1 | Vapor-Dominated Resource | | 4.6 - 7.8 | 6.1 - 10.7 |
| 6.2.1.1 | Liquid-Dominated Resource (Flashed Steam) | | 3.7 - 11.4 | 5.1 - 15.8 |
| 6.2.1.2 | Liquid-Dominated Resource (pH Modification Process) | | 3.8 - 5.2 | 5.3 - 7.2 |
| 6.2.2.1 | Liquid-Dominated Resource (Binary Cycle) | | 4.5 - 12.8 | 6.1 - 17.5 |
| 6.2.3.1 | Biphase Topping Cycle | | 4.2 - 7.6 | 5.9 - 10.7 |
| 6.2.3.2 | Biphase Bottoming Cycle | | 3.5 - 6.7 | 4.9 - 9.4 |
| | ***Hydroelectric*** | | | |
| 7.1 | Conventional Hydroelectric | | 5.1 - 11.3 | 6.4 - 13.8 |
| 7.3 | Hydro Retrofit | | 2.9 - 6.6 | 3.8 - 8.1 |
| | ***Biomass*** | | | |
| 8.1 | Direct Combustion | | 5.8 - 11.8 | 8.1 - 16.3 |
| 8.2 | Gasifier w/Engine | | 6.9 - 9.6 | 8.5 - 11.9 |
| 8.3 | Anaerobic Digester w/Engine | | 8.2 - 12.2 | 10.6 - 15.9 |
| | ***Solar Thermal*** | | | |
| 12.1.3 | Parabolic Trough Solar Hybrid (Current) (80 MW) | | 7.6 - 9.1 | 10.6 - 12.8 |
| 12.1.3 | Parabolic Trough Solar Hybrid (Current) (200 MW) | | 6.7 - 8.0 | 9.4 - 11.3 |
| ***INTERMEDIATE (20-35% Capacity Factor)*** | | **Benchmark:** | ***5.4 - 7.8*** | |
| | ***Natural Gas*** | | | |
| 2.3.1 | Conventional Combined Cycle (Benchmark) | | 5.4 - 7.8 | 7.2 - 10.1 |
| 2.4.1 | Steam Recuperated Gas Turbine | | 5.5 - 9.6 | 7.4 - 13.0 |
| | ***Solar Thermal*** | | | |
| 12.1.3 | Parabolic Trough Hybrid (Current) (80 MW) | | 11.5 - 18.4 | 16.2 - 26.0 |
| 12.1.3 | Parabolic Trough Hybrid (Current) (200 MW) | | 10.0 - 15.7 | 14.0 - 22.2 |

**TABLE 4: LEVELIZED COST ANALYSIS RESULTS**
**Commercially Available Electricity Generation Technologies**
**Utility (IOU) Ownership (continued)**

| | | | 1993 Reference Year Cents/kWh Constant $ | | | Nominal $ | | |
|---|---|---|---|---|---|---|---|---|
| ***INTERMITTENT (Capacity and Benchmark Cost Vary With Resource)*** | | | | | | | | |
| | ***Wind*** | **Benchmark:** | ***6.0*** | - | ***7.0*** | | | |
| 11.1 | Utility-Scale Wind | | 4.6 | - | 4.6 | 6.5 | - | 6.5 |
| | ***Ocean Energy Conversion*** | **Benchmark:** | ***8.1*** | - | ***9.2*** | | | |
| 14.1 | Wave Energy Conversion | | 5.8 | - | 36.0 | 7.9 | - | 49.6 |
| | ***Storage Systems*** | **Benchmark:** | ***15.2*** | - | ***15.4*** | | | |
| 16.1.1 | Conventional Pumped Hydroelectric | | 15.9 | - | 19.7 | 19.3 | - | 22.6 |
| 16.1.2 | Modular Pumped Storage | | 7.8 | - | 14.4 | 10.9 | - | 19.3 |
| 16.2 | Compressed Air Energy Storage | | 6.3 | - | 7.1 | 8.9 | - | 9.9 |
| ***PEAKING (5% Capacity Factor)*** | | **Benchmark:** | ***15.2*** | - | ***15.4*** | | | |
| | ***Natural Gas*** | | | | | | | |
| 2.2 | Simple Cycle Gas Turbine (Benchmark) | | 15.2 | - | 15.4 | 20.5 | - | 20.9 |
| | ***Storage Systems*** | | | | | | | |
| 16.1.2 | Modular Pumped Storage | | 20.7 | - | 23.1 | 26.8 | - | 30.0 |
| 16.3 | Utility Battery - Lead Acid | | 13.3 | - | 15.5 | 19.4 | - | 22.5 |

## TABLE 5: LEVELIZED COST ANALYSIS RESULTS
## NOT YET Commercially Available Electricity Generation Technologies
## Utility (IOU) Ownership

| | | | *1993 Reference Year Cents/kWh* | |
|---|---|---|---|---|
| | | | ***Constant $*** | ***Nominal $*** |
| ***BASELOAD (60-75% Capacity Factor)*** | | **Benchmark:** | ***3.9 - 4.4*** | |
| | ***Natural Gas*** | | | |
| 2.4.2 | Intercooled Steam Recuperated Gas Turbine | | 3.7 - 4.8 | 5.0 - 6.6 |
| 2.4.3 | Chemically Recuperated Gas Turbine | | 3.6 - 5.0 | 4.9 - 6.8 |
| 2.4.4 | Humid Air Turbine | | 3.1 - 4.5 | 4.3 - 6.1 |
| 2.4.5 | Intercooled Reheat Combined Cycle | | 3.5 - 4.5 | 4.9 - 6.2 |
| 2.4.6 | Intercooled Aeroderivative Gas Turbine | | 5.0 - 7.6 | 6.8 - 10.2 |
| | ***Coal*** | | | |
| 3.2.2 | Circulating Pressurized Fluidized Bed | | 4.5 - 5.4 | 6.0 - 7.3 |
| 3.2.2 | Circulating Pressurized Fluidized Bed (2005) | | 3.3 - 4.1 | 4.4 - 5.3 |
| 3.3 | Integrated Gasification Combined Cycle | | 3.9 - 5.4 | 5.0 - 6.7 |
| 3.3 | Integrated Gasification Combined Cycle (2005) | | 3.6 - 5.0 | 4.6 - 6.3 |
| | ***Nuclear*** | | | |
| 4.1 | Advanced Pressurized Water Reactor (Evolutionary) | | 5.6 - 7.0 | 7.5 - 9.4 |
| 4.1 | Advanced Pressurized Water Reactor (Passive) | | 6.4 - 7.9 | 8.7 - 10.7 |
| 4.2 | Advanced Boiling Water Reactor (Evolutionary) | | 5.6 - 7.0 | 7.5 - 9.4 |
| 4.2 | Advanced Boiling Water Reactor (Passive) | | 6.4 - 7.9 | 8.6 - 10.7 |
| | ***Geothermal*** | | | |
| 6.2.2.2 | Liquid-Dominated Resources (Kalina Cycle) | | 4.1 - 5.1 | 5.5 - 6.9 |
| | ***Solar Thermal*** | | | |
| 12.1.1 | Central Receiver Hybrid (1999) | | 5.8 - 6.5 | 8.1 - 9.1 |
| 12.1.1 | Central Receiver (2003) | | 7.2 - 8.0 | 9.9 - 11.0 |
| 12.1.1 | Central Receiver (2005) | | 6.1 - 6.8 | 8.4 - 9.3 |
| 12.1.1 | Central Receiver (Future) (2006) | | 4.6 - 5.1 | 6.4 - 7.1 |
| 12.1.3 | Parabolic Trough Solar Hybrid (Future) (80 MW) | | 7.0 - 8.4 | 9.8 - 11.8 |
| 12.1.3 | Parabolic Trough Solar Hybrid (Future) (200 MW) | | 6.0 - 7.1 | 8.4 - 10.0 |
| 12.2 | Salt Pond (1997) | | 8.5 - 10.6 | 11.6 - 14.5 |
| 12.2 | Salt Pond (2002) | | 6.7 - 8.4 | 8.7 - 10.9 |
| | ***Ocean Energy Conversion*** | | | |
| 14.3 | Ocean Thermal Energy Conversion (1998) | | 10.5 - 21.2 | 14.1 - 28.5 |
| | ***Fuel Cell*** | | | |
| 15.1 | Phosphoric Acid Fuel Cell (Current) | | 6.4 - 7.5 | 8.4 - 9.9 |
| 15.1 | Phosphoric Acid Fuel Cell (2004) | | 5.8 - 6.8 | 7.7 - 9.0 |
| 15.2 | Molten Carbonate Fuel Cell | | 7.3 - 11.2 | 9.9 - 15.2 |

## TABLE 5: LEVELIZED COST ANALYSIS RESULTS
## NOT YET Commercially Available Electricity Generation Technologies
## Utility (IOU) Ownership (continued)

| | | | *1993 Reference Year Cents/kWh* | |
|---|---|---|---|---|
| | | | *Constant $* | *Nominal $* |
| ***INTERMEDIATE (20-35% Capacity Factor)*** | | **Benchmark:** | ***5.4 - 7.8*** | |
| | ***Natural Gas*** | | | |
| 2.4.2 | Intercooled Steam Recuperated Gas Turbine | | 5.1 - 8.6 | 6.9 - 11.6 |
| 2.4.3 | Chemically Recuperated Gas Turbine | | 5.3 - 9.4 | 7.1 - 12.6 |
| | ***Solar Thermal*** | | | |
| 12.1.1 | Central Receiver (2001) | | 8.5 - 9.5 | 11.8 - 13.1 |
| 12.1.1 | Central Receiver (2004) | | 6.9 - 7.7 | 9.5 - 10.6 |
| 12.1.1 | Central Receiver (Future) (2006) | | 5.4 - 6.0 | 7.5 - 8.3 |
| 12.1.2 | Parabolic Dish w/Central Generation (1997) | | 5.6 - 14.0 | 7.9 - 19.5 |
| 12.1.3 | Parabolic Trough Solar Hybrid (Future) (80 MW) | | 10.6 - 17.0 | 14.9 - 24.0 |
| 12.1.3 | Parabolic Trough Solar Hybrid (Future) (200 MW) | | 8.8 - 13.7 | 12.3 - 19.4 |
| ***INTERMITTENT (Capacity and Benchmark Cost Vary With Resource)*** | | | | |
| | ***Solar Thermal*** | **Benchmark:** | ***11.1 - 12.2*** | |
| 12.1.2 | Parabolic Dish (Distributed Application) | | 6.9 - 19.2 | 9.7 - 26.7 |
| | ***Photovoltaics (Utility-Scale Systems)*** | **Benchmark:** | ***11.1 - 12.2*** | |
| 13.1 | Flat Plate (Current) | | 11.3 - 17.3 | 15.8 - 24.3 |
| 13.1 | Flat Plate (2005) | | 6.4 - 15.7 | 9.0 - 22.1 |
| 13.1 | Fresnel Lens Concentrator (Current) | | 13.0 - 13.2 | 18.2 - 18.5 |
| 13.1 | Fresnel Lens Concentrator (2005) | | 10.4 - 10.6 | 14.6 - 14.9 |
| 13.1 | Fresnel Lens Concentrator (Current) (50 MW) | | 10.8 - 11.0 | 15.2 - 15.5 |
| 13.1 | Fresnel Lens Concentrator (2005) (50 MW) | | 9.1 - 9.3 | 12.8 - 13.1 |
| | ***Ocean Energy Conversion*** | **Benchmark:** | ***8.1 - 9.2*** | |
| 14.2 | Tidal Energy Conversion | | 11.6 - 20.2 | 14.6 - 26.7 |

**TABLE 6: LEVELIZED COST ANALYSIS RESULTS**
**Commercially Available Electricity Generation Technologies**
**Municipal Utility (Government) Ownership**

| | | | 1993 Reference Year Cents/kWh Constant $ | 1993 Reference Year Cents/kWh Nominal $ |
|---|---|---|---|---|
| ***BASELOAD (60-75% Capacity Factor)*** | | **Benchmark:** | ***3.5 - 3.9*** | |
| | ***Natural Gas*** | | | |
| 2.1.1 | Conventional Rankine Cycle | | 4.2 - 4.7 | 6.2 - 7.0 |
| 2.1.2 | Supercritical Rankine Cycle | | 4.2 - 5.3 | 6.2 - 7.9 |
| 2.3.1 | Conventional Combined Cycle (Benchmark) | | 3.5 - 3.9 | 5.1 - 5.7 |
| 2.3.2 | Kalina Combined Cycle | | 3.7 - 5.6 | 5.4 - 8.3 |
| 2.4.1 | Steam Recuperated Gas Turbine | | 3.7 - 5.0 | 5.4 - 7.4 |
| | ***Coal*** | | | |
| 3.1 | Pulverized Coal - Subcritical | | 3.4 - 3.9 | 4.9 - 5.8 |
| 3.1 | Pulverized Coal - Supercritical | | 3.3 - 4.2 | 4.9 - 6.2 |
| | ***Nuclear*** | | | |
| 4.1 | Pressurized Water Reactor | | 5.6 - 7.8 | 8.1 - 11.2 |
| 4.2 | Boiling Water Reactor | | 5.8 - 7.9 | 8.3 - 11.4 |
| | ***Geothermal*** | | | |
| 6.1 | Vapor-Dominated Resource | | 3.6 - 6.4 | 5.3 - 9.6 |
| 6.2.1.1 | Liquid-Dominated Resource (Flashed Steam) | | 3.0 - 10.1 | 4.6 - 15.0 |
| 6.2.1.2 | Liquid-Dominated Resource (pH Modification Process) | | 3.4 - 4.4 | 5.0 - 6.6 |
| 6.2.2.1 | Liquid-Dominated Resource (Binary Cycle) | | 3.4 - 10.8 | 5.2 - 16.0 |
| 6.2.3.1 | Biphase Topping Cycle | | 3.4 - 6.5 | 5.2 - 9.8 |
| 6.2.3.2 | Biphase Bottoming Cycle | | 3.1 - 6.1 | 4.7 - 9.1 |
| | ***Hydroelectric*** | | | |
| 7.1 | Conventional Hydroelectric | | 2.9 - 5.6 | 4.7 - 9.1 |
| 7.3 | Hydro Retrofit | | 1.8 - 3.2 | 3.0 - 5.2 |
| | ***Biomass*** | | | |
| 8.1 | Direct Combustion | | 5.2 - 9.9 | 7.7 - 14.9 |
| 8.2 | Gasifier w/Engine | | 6.3 - 8.9 | 8.1 - 11.4 |
| 8.3 | Anaerobic Digester w/Engine | | 7.1 - 10.0 | 9.6 - 13.8 |
| | ***Municipal Solid Waste*** | | | |
| 9.1.1 | Mass Burn | | 1.5 - 3.4 | 2.7 - 6.0 |
| 9.1.2.1 | RDF Spreader-Stoker | | 0.9 - 8.4 | 1.6 - 12.1 |
| 9.1.2.3 | RDF Fluidized Bed | | 1.0 - 8.4 | 1.8 - 12.2 |
| 9.2.2 | Landfill Gas Recovery | | 1.6 - 3.6 | 2.3 - 5.1 |
| | ***Solar Thermal*** | | | |
| 12.1.3 | Parabolic Trough Solar Hybrid (Current) (80 MW) | | 6.3 - 7.4 | 9.6 - 11.3 |
| 12.1.3 | Parabolic Trough Solar Hybrid (Current) (200 MW) | | 5.7 - 6.5 | 8.6 - 10.0 |
| ***INTERMEDIATE (20-35% Capacity Factor)*** | | **Benchmark:** | ***4.4 - 6.0*** | |
| | ***Natural Gas*** | | | |
| 2.3.1 | Conventional Combined Cycle (Benchmark) | | 4.4 - 6.0 | 6.5 - 8.8 |
| 2.4.1 | Steam Recuperated Gas Turbine | | 4.6 - 7.7 | 6.9 - 11.5 |

## TABLE 6: LEVELIZED COST ANALYSIS RESULTS
## Commercially Available Electricity Generation Technologies
## Municipal Utility (Government) Ownership (continued)

| | | | 1993 Reference Year Cents/kWh Constant $ | Nominal $ |
|---|---|---|---|---|
| ***INTERMITTENT (Capacity and Benchmark Cost Vary With Resource)*** | | | | |
| | ***Solar Thermal*** | | | |
| 12.1.3 | Parabolic Trough Hybrid (Current) (80 MW) | | 8.7 - 13.0 | 13.6 - 20.7 |
| 12.1.3 | Parabolic Trough Hybrid (Current) (200 MW) | | 7.6 - 11.0 | 11.8 - 17.6 |
| | ***Wind*** | **Benchmark:** | ***4.8 - 5.5*** | |
| 11.1 | Utility-Scale Wind | | 3.4 - 3.4 | 5.4 - 5.4 |
| | ***Storage Systems*** | **Benchmark:** | ***10.8 - 11.1*** | |
| 16.1.1 | Conventional Pumped Hydroelectric | | 8.4 - 11.2 | 13.2 - 18.3 |
| 16.1.2 | Modular Pumped Storage | | 6.1 - 9.6 | 10.1 - 15.9 |
| 16.2 | Compressed Air Energy Storage | | 5.3 - 5.8 | 8.0 - 8.8 |
| ***PEAKING (5% Capacity Factor)*** | | **Benchmark:** | ***10.8 - 11.1*** | |
| | ***Natural Gas*** | | | |
| 2.2 | Simple Cycle Gas Turbine (Benchmark) | | 10.8 - 11.1 | 16.7 - 17.1 |
| | ***Storage Systems*** | | | |
| 16.1.2 | Modular Pumped Storage | | 12.1 - 13.7 | 20.0 - 22.6 |
| 16.3 | Utility Battery - Lead Acid | | 10.5 - 12.1 | 17.1 - 19.6 |

## TABLE 7: LEVELIZED COST ANALYSIS RESULTS
## NOT YET Commercially Available Electricity Generation Technologies
## Municipal Utility (Government) Ownership

| | | | 1993 Reference Year Cents/kWh | |
|---|---|---|---|---|
| | | | ***Constant $*** | ***Nominal $*** |
| ***BASELOAD (60-75% Capacity Factor)*** | | **Benchmark:** | ***3.9 - 4.4*** | |
| | ***Natural Gas*** | | | |
| 2.4.2 | Intercooled Steam Recuperated Gas Turbine | | 3.3 - 4.2 | 4.9 - 6.2 |
| 2.4.3 | Chemically Recuperated Gas Turbine | | 3.2 - 4.3 | 4.7 - 6.3 |
| | ***Nuclear*** | | | |
| 4.1 | Advanced Pressurized Water Reactor (Evolutionary) | | 4.0 - 5.0 | 6.7 - 8.3 |
| 4.1 | Advanced Pressurized Water Reactor (Passive) | | 4.6 - 5.7 | 7.8 - 9.6 |
| 4.2 | Advanced Boiling Water Reactor (Evolutionary) | | 4.0 - 5.0 | 6.7 - 8.4 |
| 4.2 | Advanced Boiling Water Reactor (Passive) | | 4.6 - 5.7 | 7.7 - 9.6 |
| | ***Geothermal*** | | | |
| 6.2.2.2 | Liquid-Dominated Resource (Kalina Cycle) | | 3.1 - 3.9 | 4.7 - 5.9 |
| | ***Municipal Solid Waste*** | | | |
| 9.1.2.2 | RDF/Coal Co-Firing | | 10.3 - 13.7 | 14.4 - 19.1 |
| | ***Solar Thermal*** | | | |
| 12.1.1 | Central Receiver Hybrid (1999) | | 4.9 - 5.5 | 7.4 - 8.2 |
| 12.1.1 | Central Receiver (2003) | | 5.0 - 5.6 | 7.9 - 8.8 |
| 12.1.1 | Central Receiver (2005) | | 4.2 - 4.7 | 6.6 - 7.3 |
| 12.1.1 | Central Receiver (Future Technology) (2006) | | 3.2 - 3.6 | 5.0 - 5.6 |
| 12.1.3 | Parabolic Trough Solar Hybrid (Future) (80 MW) | | 5.9 - 6.8 | 8.9 - 10.4 |
| 12.1.3 | Parabolic Trough Solar Hybrid (Future) (200 MW) | | 5.1 - 5.8 | 7.7 - 8.9 |
| 12.2 | Salt Pond (1997) | | 6.4 - 8.0 | 9.8 - 12.3 |
| 12.2 | Salt Pond (2002) | | 4.6 - 5.8 | 7.0 - 8.7 |
| | ***Fuel Cell*** | | | |
| 15.1 | Phosphoric Acid Fuel Cell (Current) | | 5.2 - 5.9 | 7.5 - 8.7 |
| 15.1 | Phosphoric Acid Fuel Cell (2004) | | 4.8 - 5.5 | 7.0 - 8.1 |
| 15.2 | Molten Carbonate Fuel Cell | | 5.5 - 8.0 | 8.3 - 12.3 |
| ***INTERMEDIATE (20-35% Capacity Factor)*** | | **Benchmark:** | ***5.4 - 7.8*** | |
| | ***Natural Gas*** | | | |
| 2.4.2 | Intercooled Steam Recuperated Gas Turbine | | 4.2 - 6.7 | 6.2 - 10.0 |
| 2.4.3 | Chemically Recuperated Gas Turbine | | 4.2 - 7.1 | 6.2 - 10.6 |
| | ***Solar Thermal*** | | | |
| 12.1.1 | Central Receiver (2001) | | 6.1 - 6.7 | 9.5 - 10.6 |
| 12.1.1 | Central Receiver (2004) | | 4.8 - 5.3 | 7.6 - 8.4 |
| 12.1.1 | Central Receiver (Future) (2006) | | 3.8 - 4.2 | 5.9 - 6.6 |
| 12.1.2 | Parabolic Dish w/Central Generation (1997) | | 4.2 - 8.8 | 6.6 - 14.4 |
| 12.1.3 | Parabolic Trough Hybrid (Future) (80 MW) | | 8.1 - 12.0 | 12.6 - 19.2 |
| 12.1.3 | Parabolic Trough Hybrid (Future) (200 MW) | | 6.7 - 9.6 | 10.4 - 15.3 |

**TABLE 7: LEVELIZED COST ANALYSIS RESULTS**
**NOT YET Commercially Available Electricity Generation Technologies**
**Municipal Utility (Government) Ownership (continued)**

| | | | ***1993 Reference Year Cents/kWh*** | |
|---|---|---|---|---|
| | | | ***Constant $*** | ***Nominal $*** |
| ***INTERMITTENT (Capacity and Benchmark Cost Vary With Resource)*** | | | | |
| | ***Solar Thermal*** | **Benchmark:** | ***8.1 - 8.9*** | |
| 12.1.2 | Parabolic Dish (Distributed Application) | | 5.3 - 14.0 | 8.2 - 22.0 |
| | ***Photovoltaics (Utility-Scale Systems)*** | **Benchmark:** | ***8.1 - 8.9*** | |
| 13.1 | Flat Plate (Current) | | 7.5 - 11.6 | 12.2 - 18.7 |
| 13.1 | Flat Plate (2005) | | 4.3 - 10.4 | 6.9 - 16.9 |
| 13.1 | Fresnel Lens Concentrator (Current) | | 8.6 - 8.9 | 14.0 - 14.3 |
| 13.1 | Fresnel Lens Concentrator (2005) | | 6.9 - 7.1 | 11.2 - 11.5 |
| 13.1 | Fresnel Lens Concentrator (Current) (50 MW) | | 7.2 - 7.4 | 11.7 - 12.0 |
| 13.1 | Fresnel Lens Concentrator (2005) (50 MW) | | 6.1 - 6.2 | 9.8 - 10.1 |

## TABLE 8: LEVELIZED COST ANALYSIS RESULTS
## Commercially Available Electricity Generation Technologies
## Non-Utility Generator (NUG) Ownership

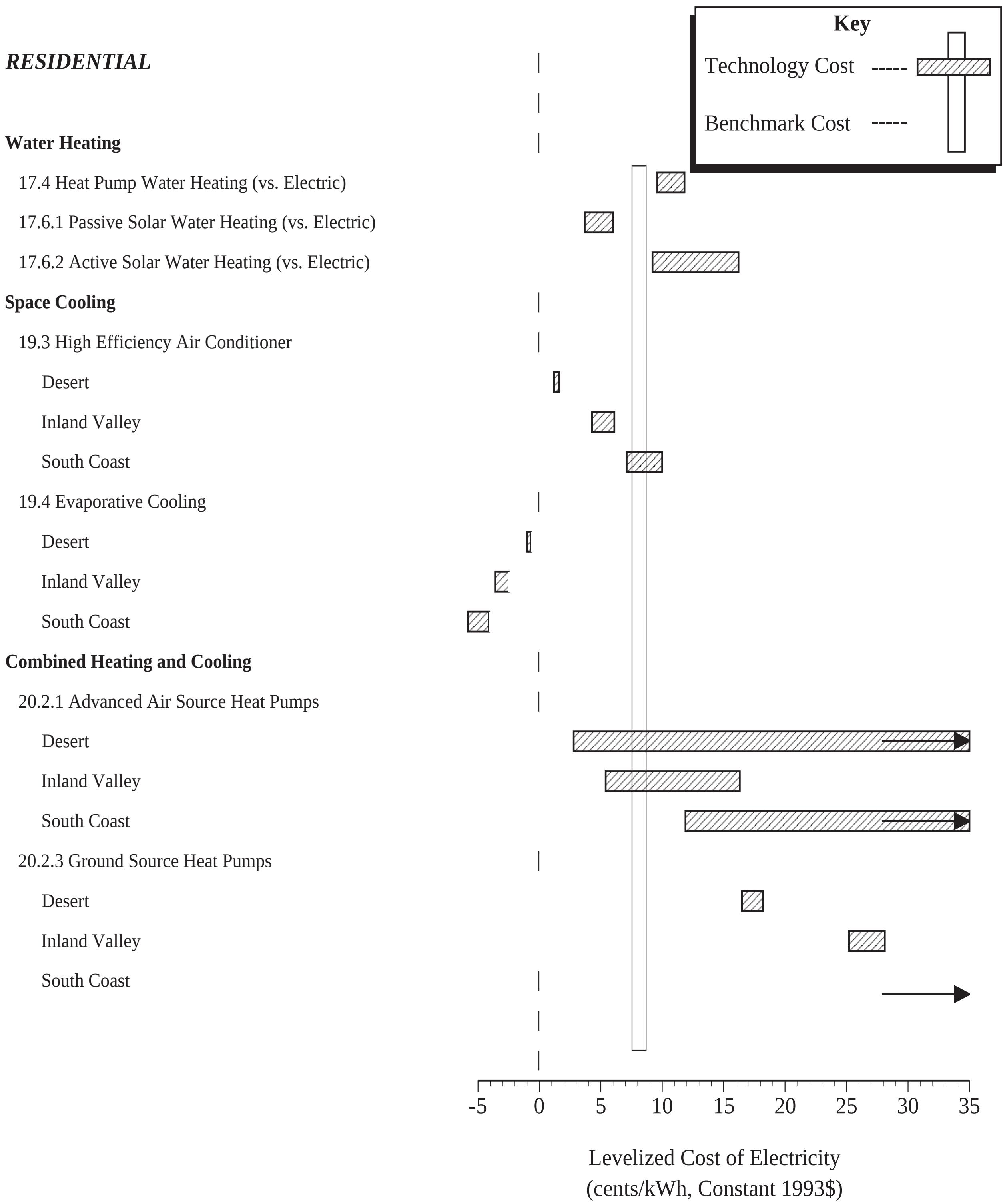
| | | | 1993 Reference Year Cents/kWh Constant $ | 1993 Reference Year Cents/kWh Nominal $ |
|---|---|---|---|---|
| ***BASELOAD (60-75% Capacity Factor)*** | | **Benchmark:** | ***3.9 - 4.4*** | |
| | ***Geothermal*** | | | |
| 6.2.1.1 | Liquid-Dominated Resource (Flashed Steam) | | 4.9 - 17.9 | 5.9 - 19.9 |
| 6.2.1.2 | Liquid-Dominated Resource (pH Modification Process) | | 4.6 - 9.2 | 5.6 - 9.9 |
| 6.2.2.1 | Liquid-Dominated Resource (Binary Cycle) | | 6.2 - 22.1 | 7.3 - 23.6 |
| 6.2.3.1 | Biphase Topping Cycle | | 5.1 - 11.4 | 6.6 - 13.6 |
| 6.2.3.2 | Biphase Bottoming Cycle | | 4.0 - 8.8 | 5.1 - 10.6 |
| | ***Hydroelectric*** | | | |
| 7.1 | Conventional Hydroelectric | | 9.5 - 41.9 | 9.2 - 32.6 |
| 7.3 | Hydro Retrofit | | 5.0 - 23.2 | 5.0 - 19.0 |
| | ***Biomass*** | | | |
| 8.1 | Direct Combustion | | 6.9 - 20.4 | 8.6 - 22.4 |
| 8.2 | Gasifier w/Engine | | 8.9 - 16.0 | 10.0 - 16.3 |
| 8.3 | Anaerobic Digester w/Engine | | 9.4 - 17.9 | 11.5 - 20.9 |
| | ***Municipal Solid Waste*** | | | |
| 9.1.1 | Mass Burn | | 5.2 - 22.4 | 6.3 - 24.9 |
| 9.1.2.1 | RDF Spreader-Stoker | | 4.4 - 21.2 | 5.2 - 23.9 |
| 9.1.2.3 | RDF Fluidized Bed | | 4.6 - 21.0 | 5.5 - 23.7 |
| 9.2.2 | Landfill Gas Recovery | | 2.9 - 8.0 | 3.3 - 8.7 |
| | ***Solar Thermal*** | | | |
| 12.1.3 | Parabolic Trough Solar Hybrid (Current) (80 MW) | | 9.0 - 15.3 | 11.5 - 18.1 |
| 12.1.3 | Parabolic Trough Solar Hybrid (Current) (200 MW) | | 7.9 - 13.4 | 10.2 - 15.9 |
| ***INTERMEDIATE (20-35% Capacity Factor)*** | | **Benchmark:** | ***5.4 - 7.8*** | |
| | ***Solar Thermal*** | | | |
| 12.1.3 | Parabolic Trough Solar Hybrid (Current) (80 MW) | | 14.9 - 37.9 | 19.1 - 44.6 |
| 12.1.3 | Parabolic Trough Solar Hybrid (Current) (200 MW) | | 12.9 - 32.6 | 16.5 - 38.3 |
| ***INTERMITTENT (Capacity and Benchmark Cost Vary With Resource)*** | | | | |
| | ***Wind*** | **Benchmark:** | ***6.0 - 7.0*** | |
| 11.1 | Utility-Scale Wind | | 6.1 - 8.9 | 7.8 - 10.5 |

**TABLE 9: LEVELIZED COST ANALYSIS RESULTS**
**NOT YET Commercially Available Electricity Generation Technologies**
**Non-Utility Generator (NUG) Ownership**

| | | | 1993 Reference Year Cents/kWh Constant $ | Nominal $ |
|---|---|---|---|---|
| ***BASELOAD (60-75% Capacity Factor)*** | | **Benchmark:** | ***3.9 - 4.4*** | |
| | ***Geothermal*** | | | |
| 1.3.1.2 | Hot Dry Rock | | 6.0 - 26.6 | 6.8 - 27.1 |
| 6.2.2.2 | Liquid-Dominated Resource (Kalina Cycle) | | 5.6 - 10.3 | 6.5 - 10.7 |
| | ***Municipal Solid Waste*** | | | |
| 9.1.2.2 | RDF/Coal Co-Firing | | 14.8 - 26.1 | 18.1 - 29.9 |
| | ***Solar Thermal*** | | | |
| 12.1.1 | Central Receiver Hybrid (1999) | | 6.9 - 10.6 | 8.7 - 12.2 |
| 12.1.1 | Central Receiver (2003) | | 10.2 - 17.5 | 12.5 - 19.3 |
| 12.1.1 | Central Receiver (2005) | | 8.8 - 15.2 | 10.8 - 16.8 |
| 12.1.1 | Central Receiver (Future) (2006) | | 6.7 - 11.5 | 8.2 - 12.7 |
| 12.1.3 | Parabolic Trough Solar Hybrid (Future) (80 MW) | | 8.3 - 14.1 | 10.6 - 16.7 |
| 12.1.3 | Parabolic Trough Solar Hybrid (Future) (200 MW) | | 7.0 - 11.8 | 9.0 - 14.0 |
| 12.2 | Salt Pond (1997) | | 11.6 - 21.7 | 14.1 - 23.5 |
| 12.2 | Salt Pond (2002) | | 10.9 - 23.1 | 11.6 - 21.1 |
| | ***Fuel Cell*** | | | |
| 15.1 | Phosphoric Acid Fuel Cell (Current) | | 8.0 - 13.1 | 9.3 - 13.6 |
| 15.1 | Phosphoric Acid Fuel Cell (2004) | | 7.1 - 11.1 | 8.2 - 11.8 |
| 15.2 | Molten Carbonate Fuel Cell | | 9.4 - 20.9 | 11.5 - 23.8 |
| ***INTERMEDIATE (20-35% Capacity Factor)*** | | **Benchmark:** | ***5.4 - 7.8*** | |
| | ***Solar Thermal*** | | | |
| 12.1.1 | Central Receiver (2001) | | 12.1 - 20.5 | 14.8 - 22.7 |
| 12.1.1 | Central Receiver (2004) | | 9.9 - 17.0 | 12.1 - 18.8 |
| 12.1.1 | Central Receiver (Future) (2006) | | 7.8 - 13.4 | 9.5 - 14.8 |
| 12.1.2 | Solar Parabolic Dish w/Central Generation (1997) | | 7.5 - 34.3 | 9.4 - 38.5 |
| 12.1.3 | Parabolic Trough Hybrid (Future) (80 MW) | | 13.8 - 35.0 | 17.6 - 41.1 |
| 12.1.3 | Parabolic Trough Hybrid (Future) (200 MW) | | 11.4 - 28.6 | 14.5 - 33.6 |
| ***INTERMITTENT (Capacity and Benchmark Cost Vary With Resource)*** | | | | |
| | ***Solar Thermal*** | **Benchmark:** | ***11.1 - 12.2*** | |
| 12.1.2 | Solar Parabolic Dish (Distributed Application) | | 9.2 - 39.2 | 11.5 - 44.5 |
| | ***Photovoltaics (Utility-Scale Systems)*** | **Benchmark:** | ***11.1 - 12.2*** | |
| 13.1 | Flat Plate (Current) | | 16.3 - 39.2 | 20.6 - 45.1 |
| 13.1 | Flat Plate (2005) | | 9.3 - 35.9 | 11.8 - 41.3 |
| 13.1 | Fresnel Lens Concentrator (Current) | | 18.8 - 29.7 | 23.8 - 34.2 |
| 13.1 | Fresnel Lens Concentrator (2005) | | 15.1 - 23.9 | 19.1 - 27.5 |
| 13.1 | Fresnel Lens Concentrator (Current) (50 MW) | | 15.7 - 24.8 | 19.8 - 28.5 |
| 13.1 | Fresnel Lens Concentrator (2005) (50 MW) | | 13.2 - 20.9 | 16.7 - 24.1 |

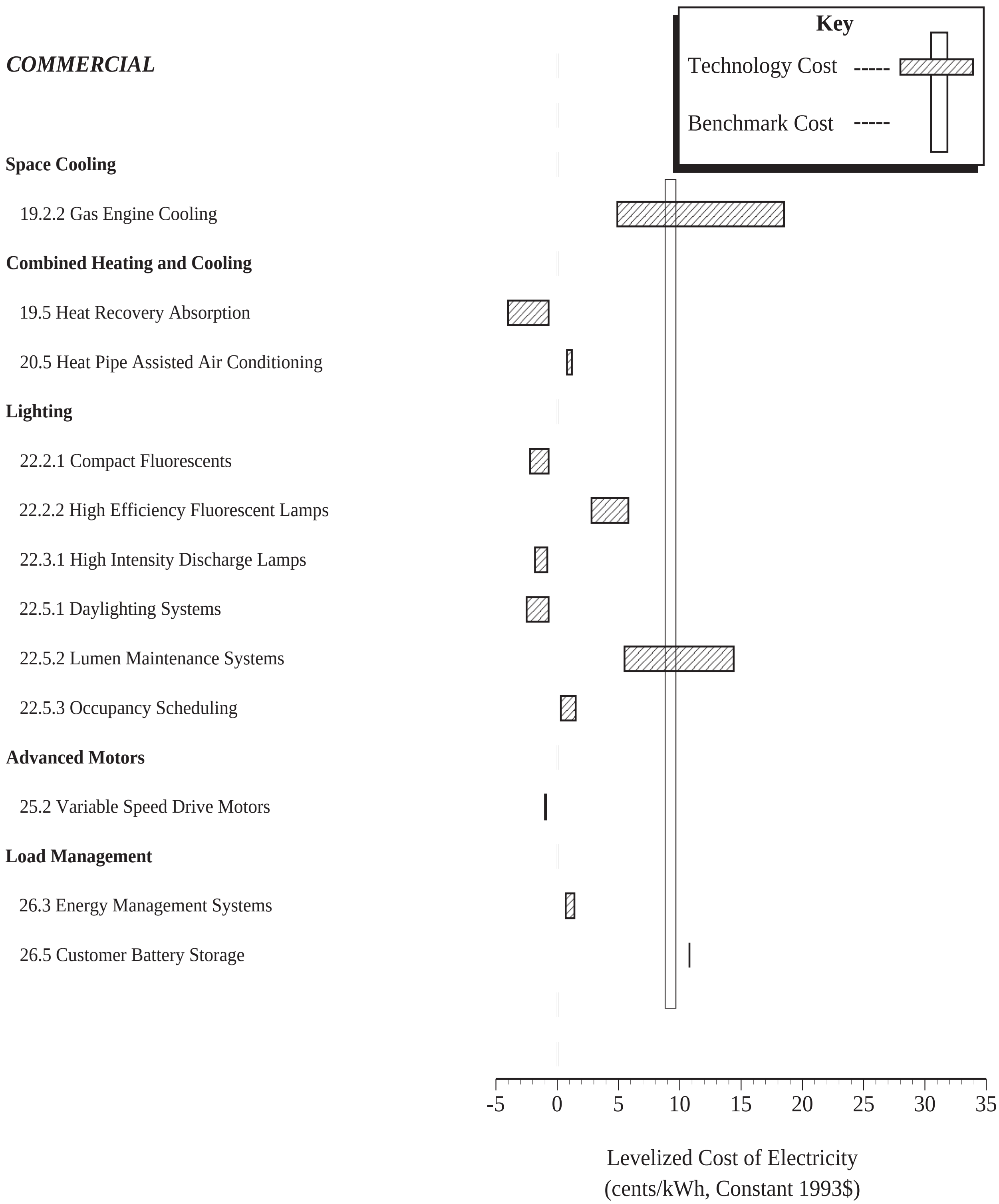
## FIGURE 10: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Commercially Available Electricity Saving End-Use Technologies**



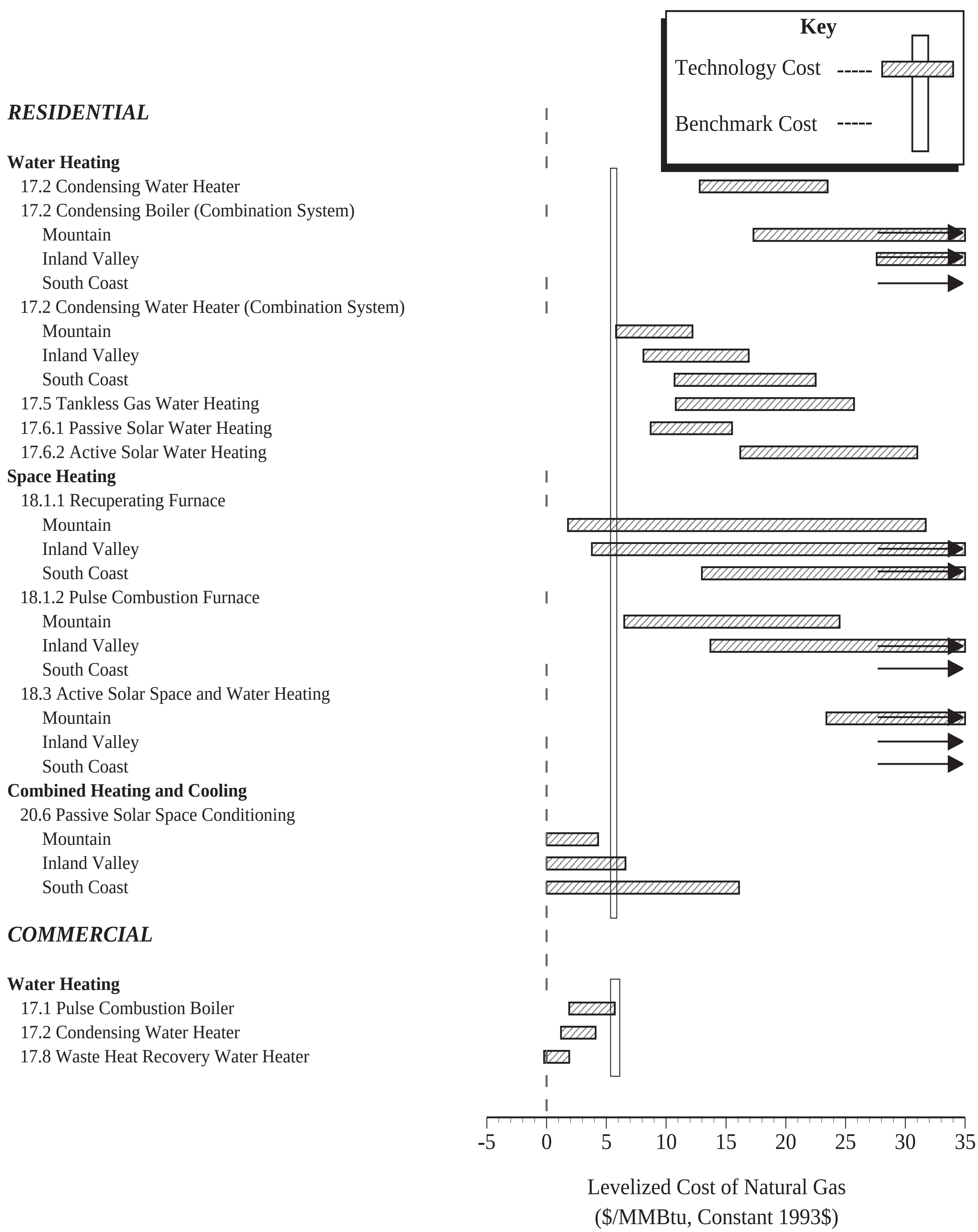
## FIGURE 10: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Commercially Available Electricity Saving End-Use Technologies**



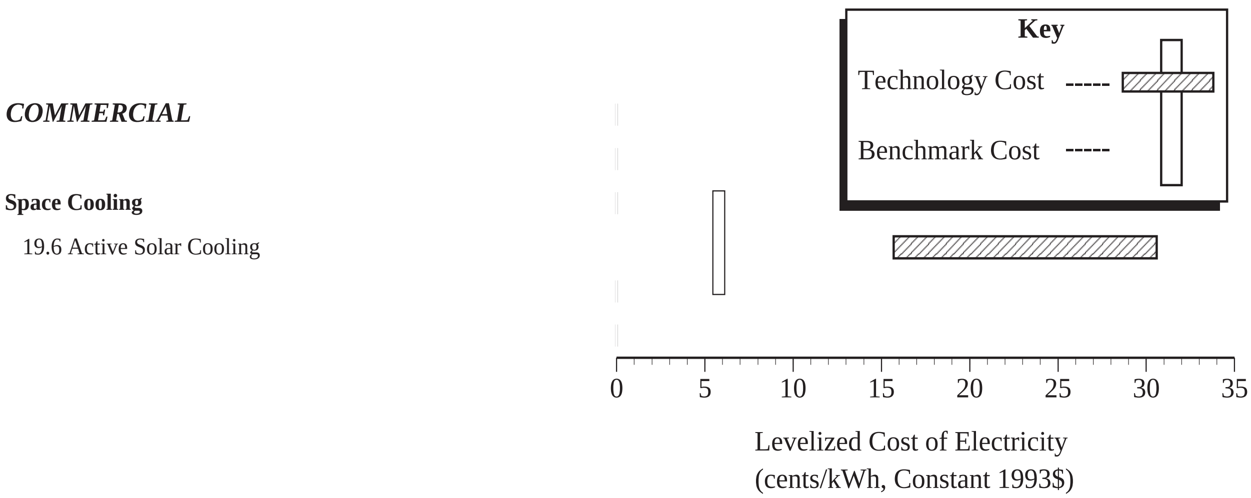
## FIGURE 11: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Commercially Available Thermal Energy Saving End-Use Technologies**



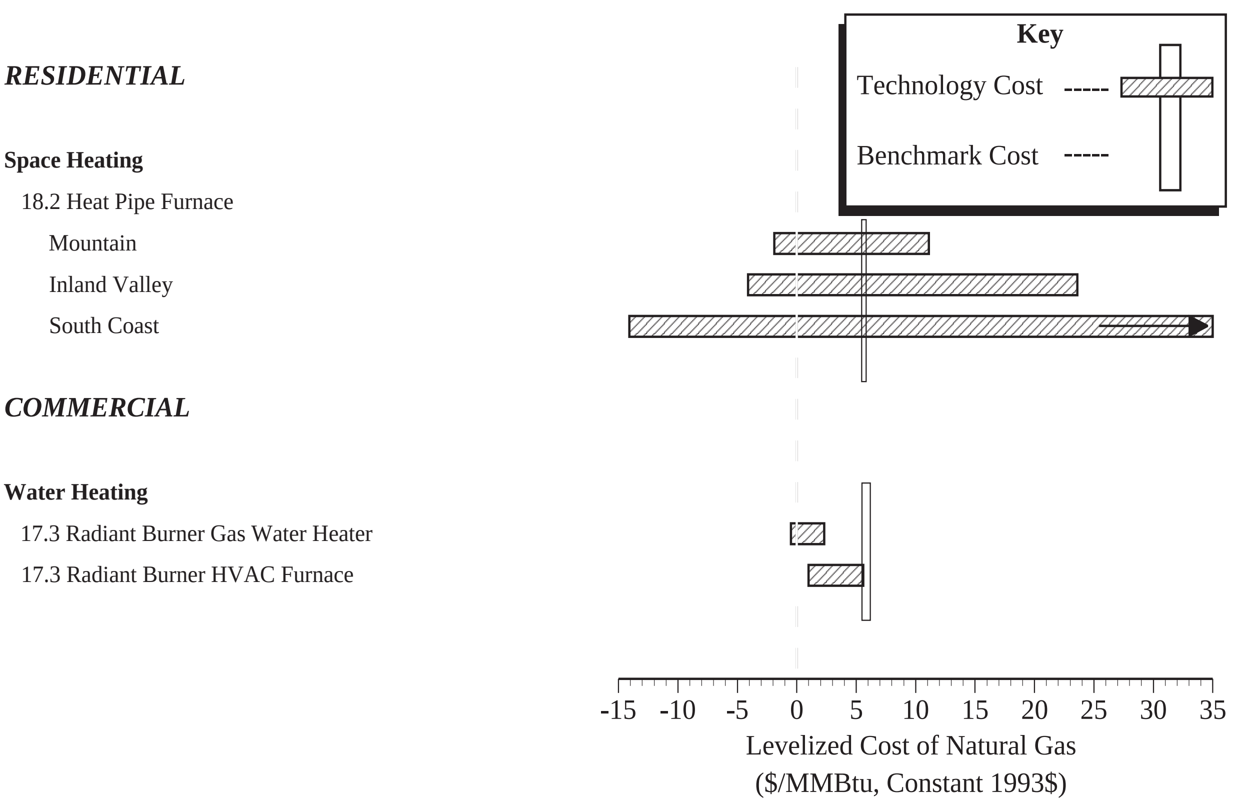
## FIGURE 12: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Electricity Saving End-UseTechnologies NOT Commercially Available**




## FIGURE 13: ECONOMIC ANALYSIS RESULTS OF ETSR TECHNOLOGIES

**Thermal Energy Saving End-Use Technologies NOT Commercially Available**



## TABLE 10: LEVELIZED COST ANALYSIS RESULTS
### Commercially Available Electricity Saving End-Use Technologies

| | | | 1993 Reference Year Cents/kWh Constant $ | 1993 Reference Year Cents/kWh Nominal $ |
|---|---|---|---|---|
| ***RESIDENTIAL*** | | **Benchmark:** | ***10.0 - 11.1*** | |
| | ***Water Heating*** | | | |
| 17.4 | Heat Pump Water Heating (vs. Electric) | | 9.6 - 11.8 | 12.3 - 14.6 |
| 17.6.1 | Passive Solar Water Heating (vs. Electric) | | 3.7 - 6.0 | 6.0 - 8.7 |
| 17.6.2 | Active Solar Water Heating (vs. Electric) | | 9.2 - 16.2 | 14.5 - 23.2 |
| | ***Space Cooling*** | | | |
| 19.3 | High Efficiency Air Conditioner | | | |
| | Desert | | 1.2 - 1.6 | 1.8 - 2.3 |
| | Inland Valley | | 4.3 - 6.1 | 6.7 - 8.5 |
| | South Coast | | 7.1 - 10.0 | 10.8 - 13.8 |
| 19.4 | Evaporative Cooling | | | |
| | Desert | | (1.0) - (0.7) | (1.3) - (1.0) |
| | Inland Valley | | (3.6) - (2.5) | (5.0) - (3.9) |
| | South Coast | | (5.8) - (4.1) | (8.1) - (6.3) |
| | ***Combined Heating and Cooling*** | | | |
| 20.2.1 | Advanced Air Source Heat Pumps | | | |
| | Desert | | 2.8 - 42.6 | 3.8 - 52.9 |
| | Inland Valley | | 5.4 - 16.3 | 7.3 - 20.9 |
| | South Coast | | 11.9 - 48.3 | 16.3 - 61.3 |
| 20.2.3 | Ground Source Heat Pumps | | | |
| | Desert | | 16.5 - 18.2 | 21.5 - 23.1 |
| | Inland Valley | | 25.2 - 28.1 | 33.0 - 35.6 |
| | South Coast | | 41.8 - 52.2 | 57.7 - 68.2 |
| ***COMMERCIAL*** | | **Benchmark:** | ***8.8 - 9.8*** | |
| | ***Space Cooling*** | | | |
| 19.2.2 | Gas Engine Cooling | | 4.9 - 18.5 | 9.2 - 24.5 |
| | ***Combined Heating and Cooling*** | | | |
| 19.5 | Heat Recovery Absorption | | (4.0) - (0.7) | (5.4) - (2.0) |
| 20.5 | Heat Pipe Assisted Air Conditioning | | 0.8 - 1.2 | 1.3 - 1.8 |
| | ***Lighting*** | | | |
| 22.2.1 | Compact Fluorescents | | (2.2) - (0.7) | (2.1) - (0.6) |
| 22.2.2 | High Efficiency Fluorescent Lamps | | 2.8 - 5.8 | 4.1 - 7.3 |
| 22.3.1 | High Intensity Discharge Lamps | | (1.8) - (0.8) | (1.6) - (0.6) |
| 22.5.1 | Daylighting Systems | | (2.5) - (0.7) | (3.4) - (0.6) |
| 22.5.2 | Lumen Maintenance Systems | | 5.5 - 14.4 | 13.8 - 23.1 |
| 22.5.3 | Occupancy Scheduling | | 0.3 - 1.5 | 1.3 - 2.6 |
| | ***Advanced Motors*** | | | |
| 25.2 | Variable Speed Drive Motors | | (0.9) - (0.9) | (1.0) - (1.0) |
| | ***Load Management*** | | | |
| 26.3 | Energy Management Systems | | 0.7 - 1.4 | 1.3 - 2.0 |
| 26.5 | Customer Battery Storage | | 10.8 - 10.8 | 14.2 - 14.6 |

## TABLE 11: LEVELIZED COST ANALYSIS RESULTS
## Commercially Available Thermal Energy Saving End-Use Technologies

| | | | *1993 Reference Year Dollars/MMBtu* | |
|---|---|---|---|---|
| | | | *Constant $* | *Nominal $* |
| ***RESIDENTIAL*** | | **Benchmark:** | ***5.4 - 5.9*** | |
| | ***Water Heating*** | | | |
| 17.2 | Condensing Water Heater | | 12.8 - 23.5 | 20.3 - 33.1 |
| 17.2 | Condensing Boiler (Combination System) | | | |
| | Mountain | | 17.3 - 35.2 | 28.2 - 50.2 |
| | Inland Valley | | 27.6 - 56.1 | 44.9 - 79.8 |
| | South Coast | | 44.1 - 89.6 | 71.7 - 127.6 |
| 17.2 | Condensing Water Heater (Combination System) | | | |
| | Mountain | | 5.8 - 12.2 | 9.2 - 17.2 |
| | Inland Valley | | 8.1 - 16.9 | 12.7 - 23.9 |
| | South Coast | | 10.7 - 22.5 | 16.9 - 18.0 |
| 17.5 | Tankless Gas Water Heating | | 10.8 - 25.7 | 18.0 - 36.9 |
| 17.6.1 | Passive Solar Water Heating | | 8.7 - 15.5 | 14.5 - 22.2 |
| 17.6.2 | Active Solar Water Heating | | 16.2 - 31.0 | 26.2 - 44.2 |
| | ***Space Heating*** | | | |
| 18.1.1 | Recuperating Furnace | | | |
| | Mountain | | 1.8 - 31.7 | 2.1 - 43.1 |
| | Inland Valley | | 3.8 - 67.3 | 4.5 - 91.5 |
| | South Coast | | 13.0 - 232.1 | 15.5 - 315.6 |
| 18.1.2 | Pulse Combustion Furnace | | | |
| | Mountain | | 6.5 - 24.5 | 9.3 - 33.3 |
| | Inland Valley | | 13.7 - 51.9 | 19.7 - 70.6 |
| | South Coast | | 47.2 - 179.0 | 67.9 - 243.6 |
| 18.3 | Active Solar Space and Water Heating | | | |
| | Mountain | | 23.4 - 40.5 | 38.1 - 57.8 |
| | Inland Valley | | 39.8 - 68.8 | 64.7 - 98.3 |
| | South Coast | | 51.9 - 89.8 | 84.5 - 128.3 |
| | ***Combined Heating and Cooling*** | | | |
| 20.6 | Passive Solar Space Conditioning | | | |
| | Mountain | | 0.0 - 4.3 | 0.0 - 7.2 |
| | Inland Valley | | 0.0 - 6.6 | 0.0 - 11.0 |
| | South Coast | | 0.0 - 16.1 | 0.0 - 26.6 |
| ***COMMERCIAL*** | | **Benchmark:** | ***5.4 - 6.1*** | |
| | ***Water Heating*** | | | |
| 17.1 | Pulse Combustion Boiler | | 1.9 - 5.7 | 4.0 - 9.0 |
| 17.2 | Condensing Water Heater | | 1.2 - 4.1 | 1.8 - 5.3 |
| 17.8 | Waste Heat Recovery Water Heater | | (0.2) - 1.9 | (0.3) - 2.4 |

## TABLE 12: LEVELIZED COST ANALYSIS RESULTS
## NOT YET Commercially Available Electricity Saving End-Use Technologies

| | | | *1993 Reference Year Cents/kWh* | |
|---|---|---|---|---|
| | | | ***Constant $*** | ***Nominal $*** |
| ***COMMERCIAL*** | | **Benchmark:** | ***5.4 - 6.1*** | |
| | ***Space Cooling*** | | | |
| 19.6 | Active Solar Cooling | | 15.7 - 30.6 | 23.8 - 41.8 |

## TABLE 13: LEVELIZED COST ANALYSIS RESULTS
## NOT YET Commercially Available Thermal Energy Saving End-Use Technologies

| | | | *1993 Reference Year Dollars/MMBtu* | |
|---|---|---|---|---|
| | | | ***Constant $*** | ***Nominal $*** |
| ***RESIDENTIAL*** | | **Benchmark:** | ***5.4 - 5.9*** | |
| | ***Space Heating*** | | | |
| 18.2 | Heat Pipe Furnace | | | |
| | Mountain | | (1.9) - 11.1 | (2.6) - 15.2 |
| | Inland Valley | | (4.1) - 23.6 | (5.6) - 32.3 |
| | South Coast | | (14.1) - 81.4 | (19.3) - 111.5 |
| ***COMMERCIAL*** | | **Benchmark:** | ***5.4 - 6.1*** | |
| | ***Water Heating*** | | | |
| 17.3 | Radiant Burner Gas Water Heater | | (0.5) - 2.3 | (0.9) - 2.8 |
| 17.3 | Radiant Burner HVAC Furnace | | 1.0 - 5.6 | 1.6 - 7.7 |

## GLOSSARY OF (SELECTED) TERMS

**Benchmark Cost** - the cost (in cents per kilowatt-hour) against which the costs of all other electric generation and storage technologies are compared. For electric generation in California, the benchmark cost is the cost of electricity generated by a combined cycle plant owned by a private utility (independently-owned utility, or IOU). For energy end-use efficiency technologies, the benchmark cost is the cost of energy, either electric or thermal, most likely to be displaced (*see* Section 3.2, Competitive Cost Analysis, of this Report Summary).

**Busbar Cost** - Busbar is a term used in the electric industry for a conductor (wire) that serves as a common connection for two or more circuits. It may be in the form of metal bars or high-tension cables. (From the ***Energy Glossary*** published by the California Energy Commission, 1991). The busbar cost refers to the cost of delivering electricity to a busbar point; for this report, busbar cost does not include transmission or distribution costs.

**Constant Dollars** - Using a base year (in this report, 1993), constant dollars exclude inflation but include real escalation over a period of years. Constant dollars are often compared to nominal dollars, which include real escalation as well as inflation (*see* Section 3.2, Competitive Cost Analysis, of this Report Summary).

**Distributed Generation** - More broadly, **Distributed Resources** (DR) or **Distributed Energy Resources** (DER). DR refers to state-of-the-art and emerging technologies for electricity generation and storage. The generation technologies are sized smaller than conventional power plants and are located in or near load centers as needed; they are said to be 'distributed' through the electric power grid, and they are grid-connected. DR technologies serve to alleviate congestion on power lines, reduce the need for additional power lines, increase system reliability, or maintain or enhance power quality. They include, but are not limited to, reciprocating engines, combustion turbines, fuel cells, small wind turbines, and photovoltaics for generation, and flywheels and batteries for storage. [From the conference proceedings of the California Alliance for Distributed Energy Resources (CADER), San Diego, CA, September 1997.]

**End-Use Efficiency** - End-use is contrasted with generation; generation is the making of electricity, and end-use refers to how electricity or any fuel is utilized after it is made and transported to its final user. End-use efficiency, then, refers to how well or how efficiently the electricity or fuel is used at the point where it is finally consumed. Recent models of motors, air conditioning systems, refrigerators, and light bulbs (such as compact fluorescent bulbs) generally increase end-use efficiency because they are designed to do the same work as older units while using less electricity or fuel.

**End-Use Technology** - see **End-Use Efficiency** above. End-use technologies are the equipment or devices that utilize electricity for services sought by consumers (cooling, heating, motive power, etc.). Examples are refrigerators, air conditioners, space heaters, water heaters, and motors.

**Fuel Cycle** - the full cycle of an energy source including exploration, extraction, transportation to the site of processing, processing, transportation to the point of use, combustion or other energy release, and control and disposal of waste. (From Appendix A, Section 1.0, of the ETSR).

**Levelized Cost** - the average cost over the lifetime of a facility, with future costs discounted by the time value of money (*see* Section 3.2, Competitive Cost Analysis, of this Report Summary).

**Nominal Cost** or **Nominal Dollars** - see **Constant Dollars** above.